

The University of Adelaide



REPORT

of the

WAITE AGRICULTURAL RESEARCH
INSTITUTE

SOUTH AUSTRALIA

and associated activities of the

COMMONWEALTH SCIENTIFIC
AND INDUSTRIAL RESEARCH
ORGANIZATION

1954-1955



REPORT OF
THE WAITE AGRICULTURAL RESEARCH INSTITUTE
AND ASSOCIATED ACTIVITIES OF THE
COMMONWEALTH SCIENTIFIC AND INDUSTRIAL
RESEARCH ORGANIZATION



PROFESSOR J. A. PRESCOTT, C.B.E., D.SC., F.R.S.

*Retired from the position of Waite Professor of Agricultural Chemistry and Director of the
Institute, 31st December, 1955.*

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The University of Adelaide

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The Waite Agricultural Research Institute

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Cytologist: K. ABELE, M.A., Ph.D.

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Systematic Botanist: D. E. SYMON, B.Ag.Sc.

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K. M. DOULL, M.Ag.Sc.; D. A. MAELZER, B.Sc. (Sheep Pastures).

Technical Assistant: HELEN M. BROOKES.

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Head of Department and Reader in Plant Pathology: C. G. HANSFORD,
M.A., Sc.D.

Senior Plant Pathologist: N. T. FLENTJE, M.Sc., Ph.D.

Senior Microbiologist: J. H. WARCUP, M.Sc., Ph.D.

Plant Pathologists: A. KERR, B.Sc., Ph.D.; N. C. CROWLEY, M.Sc.

Nematologist: J. M. FISHER, B.Sc.Agr.

PLANT PATHOLOGY (*continued*)

Plant Pathologist (Gummosis): M. V. CARTER, B.Ag.Sc.

Technical Assistants: S. R. HOCKLEY, LEA WICHMAN.

Laboratory Assistants: NADIA H. BRESSLER, HELEN M. LEWIS, JANETTE R. MARTIN.

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Plant Physiologist: N. G. MARINOS, B.A., M.Sc., Ph.D.

Technical Assistant: MARGARET M. SEMMENS.

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Manager: K. A. PIKE, R.D.A.

Foreman: A. W. DICK.

Technical Assistant: R. M. FEUERHEERDT.

MEMBER OF THE STAFF WHO WAS ABSENT ON STUDY LEAVE DURING 1954-1955:

C. G. HANSFORD.

TEMPORARY AND VOLUNTARY WORKERS DURING 1954 AND 1955:

C. M. JOHNSON (Agric. Chem.), A. J. JEEVARATNAM (Agric. Chem.), R. H. SEDGLEY (Agron.), K. B. RAJBHANDARY (Agron.), HLA AYE (Agric. Chem.), J. L. DAVIDSON (Agron.), W. HARAHAP (Ent.), R. R. RAWAT (Ent.), J. S. KANWAR (Agric. Chem.), A. S. ATWAL (Ent.).

MEMBERS OF THE STAFF WHO HAVE LEFT FOR OTHER APPOINTMENTS SINCE JANUARY 1, 1954:

A. G. TYSON, P. P. BONNEMAISON, C. R. KLEINIG, F. M. HILTON, IRENA MATHISON, F. L. MILTHORPE, H. G. ANDREWARTHA, T. O. BROWNING, B. A. ROARK.

DECEASED:

B. HOROWITZ.

James Arthur Prescott

JAMES ARTHUR PRESCOTT joined the staff of the newly-formed Waite Agricultural Research Institute as first Waite Professor of Agricultural Chemistry in 1924. He came to the University of Adelaide from Egypt where he had been the chief chemist of the Sultanic Agricultural Society and supervisor of field experiments at the Bahtim Experimental Station. When he arrived Professor Prescott held the degree of M.Sc. (Manchester) and in 1932 he was awarded the degree of D.Sc. in Adelaide. Early in 1938, when the late Dr. A. E. V. Richardson resigned from the Directorship of the Waite Agricultural Research Institute, Professor Prescott was appointed to the position, and he directed the Institute through the difficult war and post-war periods. In 1950 he was elected a Fellow of the Royal Society, London, and he is a foundation member of the Australian Academy of Science.

The study of soils has always been a major part of Professor Prescott's work in his Department of Agricultural Chemistry, and in 1927 he was asked by the Council for Scientific and Industrial Research to direct the early soil survey work in the Murray Valley. The increase in the importance of the soil survey work was recognized when in 1929 C.S.I.R. created the Division of Soils. Professor Prescott accepted the appointment as Chief of the Division, and held the position jointly with his University commitments until 1947. As chairman of the Technical Committees of the Commonwealth Research Station, Merbein, and the Irrigation Research Station, Griffith, and as a member of the State Committee, he still actively contributes to the work of the Commonwealth Scientific and Industrial Research Organization.

In 1934, the University of Adelaide appointed an officer to investigate the spoilage of wine during shipment to England, and from 1935 to 1938 Professor Prescott was a member of the committee established by the University to exercise general direction of the work. C.S.I.R. in 1938 set up a committee on Oenological Research to continue the supervision and he was appointed chairman. Last year the Commonwealth Government passed the legislation necessary to establish the Australian Wine Research Institute, and Professor Prescott has been appointed to the foundation council of this Institute.

Many learned societies have benefited from his keen interest in their work, and he has been President of the Royal Society of South Australia (1932-33), President of the Royal Australian Chemical Institute (1937-38), President of the Australian Institute of Agricultural Science (1940-41). The many awards he has received from these and other bodies include the H. G. Smith Memorial medal (1931), the Sir Joseph Verco medal (1938), the Farrer medal (1948), the gold medal of the Royal Geographical Society of Australasia (1949), the medal of the Australian Institute of Agricultural Science (1950), and the Mueller medal (1954).

In 1947 he was honoured by His Majesty the late King George VI appointing him a Commander of the Order of the British Empire.

Professor Prescott has been overseas on a number of occasions. In 1934 and in 1952 he visited Europe and, during the 1934 visit, he spent some time in Russia. In 1947 he was a member of the Scientific Delegation representing

Australia at a Conference in Patna, India, and in 1951 he led an agricultural mission from Australia to Pakistan.

He has been a member of the Advisory Board of Agriculture in South Australia since 1938 and his keen interest in agriculture and particularly in the Agricultural Bureaux has been recognized by his election last year as a Life Member of the Agricultural Bureau of South Australia. He is a member of the Roseworthy Agricultural College Council, a member of the Joint Committee for the W.E.A. Tutorial Classes, and also of the State Documentary Films Committee and Chairman of Scotch College Council.

January, 1956.

J.T.H.

The Waite Agricultural Research Institute

1. INTRODUCTION.

The foundation of the Waite Institute was made possible as a result of the gift of Peter Waite to The University of Adelaide of land and property at Glen Osmond, together with an endowment.

The land comprises the Netherby Estate (112 acres) and Claremont (53 acres) adjoining the main estate of Urrbrae, making a total of 299 acres as the original gift to the University for the Institute, in addition to 114 acres to the South Australian Government for an Agricultural High School. The University has since purchased 80 acres of the Springfield estate adjacent to Netherby and 10 acres of Alverstoke for the purposes of the Institute.

Including investments to the value of £58,450, the total value of the gift was estimated at £100,000; the annual Government subsidy of five per cent. amounted to £5,000, and work began with an income of about £8,000.

The first appointments to the staff were made in 1924 and 1925.

The first three laboratories were those endowed by the late Sir John Melrose, the family of the late John Darling, and the family of the late Ranson Mortlock. A fourth laboratory was completed in 1947.

In addition to the laboratories, a range of glasshouses, a cool house for biological work in the summer months, two implement sheds, a woolshed and a cereal barn have been erected since 1925.

Endowments subsequent to the original one of Peter Waite have included those of the late Mrs. Elizabeth Macmeikan, Mr. Hugh Hughes, Mr. W. D. Grigg, and Mr. W. H. Sandland. The Ranson Mortlock Trust Fund was established in 1936 by the family of the late Mr. Frederick Ranson Mortlock for research in connection with the management of pastoral lands in the more arid regions. Mr. J. T. Mortlock subsequently generously supported these investigations and on his death in 1950 made financial provision for their continuation. Mrs. J. T. Mortlock contributed a further capital sum during 1952.

Apart from its original and subsequent endowments, the Institute derives its main income from appropriations under Acts of Parliament of South Australia.

Since 1927 the Division of Biochemistry and General Nutrition of the Commonwealth Scientific and Industrial Research Organization has maintained at the Waite Institute a field station equipped with feeding pens for the nutrition of sheep under experimental conditions.

Since 1929 the Waite Institute has been the headquarters of the Division of Soils and since 1935 has housed the Oenological Research Unit of the Commonwealth Scientific and Industrial Research Organization.

For the years 1954 and 1955 under review a total sum of £8,563 was received from the Wool Research Trust Account of the Commonwealth for research into problems associated with sheep pastures, including the summer nutrition of sheep and several insect pests of pastures.

Under the original deed of gift it was provided that portion of the estate containing an area of 67 acres should be held in perpetuity as a public park. Effect has been given to this provision by the establishment of the Waite Arboretum, in which trees can be grown to demonstrate their value for shelter

and ornament, and their adaptability to the local soil and climate. The Arboretum now has 1,350 trees, including varieties belonging to 630 different species. The first plantings were made in 1928.

The Library of the Waite Institute is designed to meet the needs of a research staff, and the policy is to make it as complete a reference library as possible on matters relating to agricultural science and its related scientific disciplines. The present total of books is 4,125, and of bound periodicals, 6,135.

The Department of Genetics was transferred to the University at North Terrace in May, 1954. Appointments have been made to continue the work on Plant Breeding and Crop Genetics at the Institute.

During the two years under review, the goodwill and co-operation of a number of people and organizations have been given and such assistance from the following is gratefully acknowledged: The Director, Botanic Gardens, Kew; The Director, Commonwealth Mycological Institute; Mr. D. G. Quinn, Viticultural Research Station, Rutherglen, Victoria; Mr. A. W. Allan, Viticultural Nursery, Wahgunyah, Victoria; The Yudnapinna Pastoral Company and Mr. R. Dean; Mr. E. A. Wirth, Delamere; The Principal, Roseworthy Agricultural College; The South Australian Brewing Co. Ltd.; Messrs. Elder, Smith & Co. Ltd.; Mr. L. J. Pym, Avon; Messrs. H. B. and H. V. Frayne, Meningie; Personnel of Land Development Scheme, A.M.P. at Brecon; Mr. K. M. Lowe, Pitlochry, Chinaman's Well; Mr. M. Dickson, Cungenah; Mr. L. Linke, Goode.

2. SCIENTIFIC WORK OF THE INSTITUTE.

The scientific work of the Institute is centred round the study of the principles of crop and pasture husbandry and of the scientific disciplines which may be associated with this aspect of agriculture. Animal husbandry is not a feature of the activities of the Institute except in so far as it is necessary for the study of pastures. The main subjects of investigation may be included in the following groups:

Agronomy and Agrobiology.

The investigation of the factors affecting the production of farm crops and the improvement, establishment and utilisation of pastures under the wide range of rainfall conditions prevailing in South Australia.

Plant Breeding and Crop Genetics.

The improvement of crop, pasture and horticultural plants and the investigation of principles of inheritance in these species.

Plant Physiology.

The investigation of the metabolism and growth of plants of agricultural importance, especially the role of carbohydrate nutrition and growth-regulating substances.

Plant Pathology.

The investigation of the diseases of agricultural and horticultural crops and of forest trees.

Entomology.

The investigation of the insects and mites affecting agriculture, and in particular problems of agricultural and horticultural crops, of stored products and of forestry.

Agricultural Chemistry.

The classification of soils; the investigation of soil fertility problems; the chemical study of plant viruses; the chemical study of pastures and plant biochemistry in general.

The Waite Institute, in addition to its principal function of research, provides scientific advisory services in systematic botany, plant pathology and entomology to the Minister responsible for the State Departments of Agriculture and of Woods and Forests.

3. TEACHING WORK OF THE INSTITUTE.

The University of Adelaide maintains a School of Agricultural Science in which a four-year course of instruction leads to the Degree of Bachelor of Agricultural Science. Teaching during the first two years is given in Science Departments while the Institute is principally responsible for teaching in the third and fourth years. Certain subjects are taken at the Roseworthy Agricultural College, more particularly tuition in Animal Production. The courses given at the Institute are those in Agriculture, Agricultural Chemistry, Soil Science, Microbiology, Plant Pathology, Entomology, Agricultural Botany, Plant Breeding and Biometry.

Post-graduate teaching is available in the several departments, leading to the Honours Degree, Master's Degree, or the Ph.D.

The Work of the Institute

Agronomy

During the past three decades a great part of the agronomic research in southern Australia has been devoted to the establishment of improved pastures. In all instances this has involved the use of introduced pasture plants, more particularly from the Mediterranean basin, and with emphasis over great areas on subterranean clover (*Trifolium subterraneum*). Sometimes sown pastures have replaced less productive swards of native plants, in others the starting point has been worthless scrub or heath. Invariably, the effective use of legumes to build soil fertility has needed fertilizer application, with superphosphate as the basic treatment and with one or more trace elements commonly playing an essential part.

Much remains to be done in further defining and developing our range of species and strains for pasture improvement, and in filling in the gaps in our knowledge of field nutrition in many environments. Nevertheless, there are now regions in which these aspects are sufficiently understood to permit satisfactory pasture development and where, as a consequence, emphasis is moving more strongly towards effective utilization of these improved, but usually far from perfect, pastures. It is with this in mind that the agronomy programme has been extended during the past two years to include research on problems of the defective nutrition during the summer months of sheep grazing on improved pastures in the Mediterranean-type environment of the Institute.

Work is being expanded in several other fields. The pasture species problem is being tackled by the ecological, physiological and genetical study of the range of material available in various genera. It is significant that no single strain of pasture plant in current use in Australia has been bred in this country. While considerable success can be claimed in the commercial development of naturally occurring ecotypes collected both in Australia (as inadvertent introductions) and overseas, it is only in the past few years that effective breeding programmes have come into being. It may seem surprising that Australia has been apparently laggard in such work. In fact, the opportunity for tremendous advances simply by the direct use of existing ecotypes or strains has been so great that pasture plant breeding has tended to be regarded as a refinement which could be deferred for many decades. But it is now more clearly recognized that even an extensive range of ecotypes will not necessarily include closely adapted material and that breeding must be actively pursued in our pasture plants as it has for over half a century in our crop plants.

Studies on crop physiology continue, with unexpected and interesting results in the study of the germination and early growth of subterranean clover. Other studies reported below, which have continued or begun since the previous report of the Institute, are those on soil aeration and plant growth, on the ecology of earth worms, and in experimental taxonomy.

1. PERMANENT ROTATION EXPERIMENT (C1).

This experiment, which was commenced in 1925, includes a comparison of ten systems of crop rotations in which the principal crop is wheat. A permanent plot of sown pasture is also maintained in the experiment.

The mean yields for the period 1925-1955 (both grain and total produce) together with the yields from the 1954 and 1955 seasons are given in Tables 1 and 2 on pages 40 and 42. The number of years of record on which long-term means are based was standardized in the previous report (1952-53). The first year of record in each case is taken as the first season's crop after a full cycle pretreatment. Several rotations, particularly those involving leys up to four years, have been in progress only since 1949 and the cumulative effect of such rotations will be in evidence only after the lapse of several more cycles.

In the 1952-53 report, the beneficial effect of broader rotations on the yield of wheat was shown for the 1953 season. The following table shows a comparison of the yields for the 1954 and 1955 seasons. The season 1954 may be regarded as an "ideal" growing season, while the 1955 season an excessively wet one, in which wheat yields were the lowest recorded at any time since the establishment of the Institute.

Rotation	Yield in bushels per acre	
	1954	1955
Wheat, continuously	16.7	3.9
Wheat, bare fallow	19.4	8.8
Wheat, peas	18.5	8.0
Wheat, oats, fallow	31.9	5.9
Wheat, pasture, fallow	35.3	14.4
Wheat, oats, pasture, fallow	52.6	24.1

2. INVESTIGATIONS ON FORAGE CROPS AND TEMPORARY PASTURE IN FOUR-COURSE ROTATIONS WITH WHEAT (C53).

The following rotations are on trial to compare the effects of various forage crops and pasture treatments on soil fertility, using wheat as the reference crop:

1	2	3	4	5
Fallow Wheat Fallow Wheat	Fallow Wheat Oats Pasture	Fallow Wheat Oats* Pasture	Fallow Wheat Peas Pasture	Fallow Wheat Peas Grazing Oats

* With added ammonium sulphate.

The pasture phase in rotations 2, 3 and 4 is Wimmera rye-grass and in 5, grazing oats. Half of each plot sown to forage is harvested each year and the other half plot is grazed by sheep.

Changes were made in the original layout of rotations and the results presented in Table 4 are means from 1949 onwards which are comparable for all treatments. The results of the 1954 and 1955 seasons are given in Tables 3 and 5. Mean yield data have been based only on data collected after a full cycle pre-treatment. The effect of season on the magnitude of yield differences between rotations exploitive and non-exploitive of nitrogen as shown in the previous report, is again apparent in the comparison of the 1954 and 1955 yield data.

The yield over the whole experiment in 1955 is the lowest recorded. Examination was made of soil structure, soil water content at seeding, soil phosphorous and nitrogen status and degree of weed infestation and it is hoped to relate these factors to both cropping system and the yield of wheat during 1955.

So far preliminary collation of the data has not shown clear relationships between yield and soil conditions. The most striking result to hand is the poor establishment on these badly structured soils. Over the range of rotation treatments, the bulk density (apparent density) ranged from 1.51 to 1.59. Water content of the surface soil was 20-25 per cent. on an oven dry basis at seeding and for the following 5 weeks. During this period there were nearly 7 inches of rain which was recorded on 23 days. Under these conditions the extremely low values of 5-10 per cent. of viable seed sown were recorded for the establishment of wheat. On plots of C92 sown on the same day, but with bulk density as low as 1.40, the establishment was 70-80 per cent.

The relationships obtained between bulk density and establishment of wheat over a number of experimental plots showed also that the time after sowing at which heavy rain occurred also appears to be important. Until rain falls the bulk density of the newly cultivated plots is quite low, 1.25-1.35. With rain the cultivated surface subsides with corresponding increase in bulk density. The degree of collapse is dependent on the water stability of the aggregates and this is the major determinant of the bulk density throughout the remainder of the season. On plots sown on 9th June, there was little evidence of dependence of establishment on soil structure. With the same range of bulk density but with the plots sown on 10th June there was a steady gradation from 70-80 per cent. establishment at a bulk density of 1.40 to 20-25 per cent. establishment at a bulk density of 1.58. The rainfall just after seeding was: June 13th, 66 pts.; June 15th, 2 pts.; June 16th, 121 pts.; June 17th, 73 pts.; June 18th, 36 pts. It is suggested that seed sown on 9th June may have been at a point in the germination process at which it was able to survive a period of waterlogging.

3. INFLUENCE OF PASTURES AND FORAGE CROPS ON THE YIELD OF WHEAT IN ROTATIONS OF VARYING DURATION (C92).

The rotations on trial are:

- (a) Fallow-Wheat.
- (b) Peas-Wheat.
- (c) Two Years Pasture-Fallow-Wheat.
- (d) Three Years Pasture-Wheat.
- (e) Six Years Pasture-Wheat-Wheat.

The results to hand are summarised in Tables 6 and 7. In 1954 and 1955 the first two blocks of C92 gave comparable yield data from all rotations. The experiment is being progressively terminated, but the past treatments have resulted in sets of plots with a wide range of soil conditions. These are now being used to follow the deterioration of the soil under sustained cropping both from soil physical and chemical aspects. It is hoped that the relative contributions of soil structure and soil nitrogen can be ascertained from this project.

The yields for 1954 and 1955 seasons enable comparisons to be made of the yield of wheat on plots of similar physical and chemical status but during very different seasons. The table below shows the comparison of both grain and

total produce for the two years: in a 'good' year (1954) and an excessively wet year (1955):

	Yield			
	Grain Bushels per acre		Total Produce Cwt. per acre	
	1954	1955	1954	1955
(a) Fallow—Wheat	28.9	11.3	47.8	27.2
(b) Peas—Wheat	26.4	25.2	34.8	34.0
(c) Two Years' Pasture—Fallow— Wheat	50.1	26.5	73.5	48.4
(d) Three Years' Pasture—Wheat	35.9	21.4	51.2	37.6
(e) Six Years' Pasture—Wheat— Wheat	22.1	4.5	30.4	13.6

The following table gives figures for bulk density and total nitrogen status of the treatments:

	Bulk Density	Total Soil N%
(a)	1.58† (1.52)*	0.075
(b)	1.41†	0.088
(c)	1.54† (1.43)*	0.094
(d)	1.37† (1.30)*	0.099
(e)	1.41†	0.102

* 1954 determinations, † 1955 determinations.

McIntyre (unpublished data) has shown an appreciable decline after pasture in the water stability of aggregates during the fallow phase of treatment (c). During 1954 the significance of this was apparent in the high bulk density figures obtained. However, under the more severe conditions of 1955, the collapse appears to have been very much greater relative to that shown by plots following straight after pasture (e.g. treatment (d)). The high bulk density in treatment (a) is a reflection of the severe structure loss under a wheat-fallow system. The extremely poor yield of the second wheat crop following six years pasture cannot at present be interpreted in terms of bulk density or nitrogen content of the soil.

Block III was wound up in 1954, and four nitrogen treatments from 0 cwt. to 4 cwt. per acre of ammonium sulphate were superimposed on the original five treatments. Regardless of initial nitrogen status, when yield was plotted against added nitrogen, it was apparent that the maximum dressing applied was insufficient. Nitrogen was still limiting at 4 cwt. per acre over a wide range of soil structure and initial soil nitrogen status. The magnitude of the response to nitrogen (yield at N_4 minus yield at N_0) shows some relation to soil structure but other factors have exerted profound influences. The fate of the applied N will not be known until analyses of plant material have been completed.

4. TOP-DRESSING OF NATURAL PASTURE (P1).

This permanent field experiment was commenced in 1925 in order to follow the effects of different forms of added phosphate on the yield, botanical composition and carrying capacity of natural pasture.

Phosphorus, at the rate of 40 lb. of P_2O_5 per acre per annum, is added as basic slag, ground rock phosphate or superphosphate. A plot receiving sodium nitrate at 78 lb. per acre plus superphosphate is also included.

The results for 1954 and 1955 and mean values for the period of the experiment are given in Tables 8 and 9 on pages 48 and 49.

5. CROP STUDIES.

(a) Grain Legume Investigations. In 1954 field experiments were commenced to test various species and strains of grain legume for yielding ability in comparison with the "White Brunswick" strain of *Pisum sativum*, the legume at present most commonly used for grain production in South Australia. Material was obtained from the Mediterranean Region via the Plant Introduction Section of C.S.I.R.O., from various sources within Australia and from overseas by direct negotiation. Altogether, some 150 lines representing 24 species have been assembled.

Trials in the first year involved sowing in rows for quarantine purposes, general observation and seed increase. Reliable yield figures were not obtained. Most lines were re-sown in 1955 in plot and uniform row length experiments, from which a considerable quantity of useful data on establishment, early growth, flowering maturity, shattering behaviour and yielding ability were secured; "White Brunswick" was used as a control. The year was not a particularly favourable one because of very wet conditions during the two months immediately following sowing at the end of May. However, under these conditions approximately one-third of the 85 lines tested were significantly ($P > .001$) superior in yield to the control. Promising species include *Vicia sativa*, *Lathyrus cicera*, *Vicia faba* and *Pisum sativum*. Most common in the low yielding groups were varieties of *Cicer arietinum*, *Vicia disperma*, *Vicia hirsuta* and *Lupinus* spp. Selections for inclusion in 1956 trials have been based on grain production, earliness, vigour of establishment, and freedom from shatter.

While definite conclusions cannot be drawn from one year's results it seems possible that legume grain production in southern Australia may be considerably improved by the use of new species and strains.

(b) The results of comparative crop trials to compare the yielding potentialities of wheat, linseed, safflower and rape under similar conditions at the Waite Institute are shown on page 50.

6. SOIL FERTILITY.

(a) Measurements are being made of the abundance of earthworms under sown pastures at the Waite Institute and of their action on the soils. The most common earthworms are the peregrine forms—

Allolobophora caliginosa (Sav.) forma *trapezoides* (A. Duges)

Allolobophora caliginosa (Sav.) forma *typica*

Eisenia rosea (Sav.)

Octolasion cyaneum (Sav.).

Under a ten-year-old pasture on Urrbrae loam the total worm population in July, 1955, weighed 150 g/m². Various methods of sampling were compared.

The electrical method of Doeksen (1950) gave about 90 per cent. recovery in moist soils, but the potassium permanganate method of Cernovitov and Evans (1947) gave low values.

In the Mediterranean-type climate of Adelaide, earthworms oversummer in a quiescent state at depths ranging from 25 to 75 cm. During the growing season most are found within the top 15 cm. The species present cast chiefly in cavities beneath the soil surface. Despite a high earthworm population, only 2,800 lb. per acre of oven dry soil was returned to the surface in 1955. The total rate of casting at 15° C. in a loam at field capacity varied from 0.2 to 0.3 g. of oven dry soil per gram of bodyweight per day, the rate being higher for young than for mature worms.

(b) The effect of grass root growth on the hydraulic conductivity of a sandy loam has been measured at low tensions. Root growth has been accompanied by a steep fall in the hydraulic conductivity measured at a mean tension of 30 cm. Xylem elements of grass roots severed near the soil surface failed to conduct water, possibly because of the formation of air locks. New apparatus was devised in the course of this work to measure the hydraulic conductivity of undisturbed core samples. Simple tensiometers of high permeability were constructed from "Porvic" plastic membrane.

(c) A direct method of measuring the size distribution of the larger pores in soil has been refined. Samples are impregnated under vacuum with a styrene plastic, and polished sections are examined at $\times 20$ to $\times 30$ magnification. The method is being used to study changes in pore size distribution caused by root growth.

(d) Measurements were made of oxygen diffusion rates and oxygen concentrations in the soil under three rotation treatments. The diffusion rate was then related to water-free porosity. The diffusion rate at low water-free porosities was found to be lower than that calculated from Penman's equation and at higher water-free porosities (ca. 0.40 cc/cc) slightly higher than calculated values. It was reasoned that in a system soil-water-air, the available cross section of air space in any plane could only be given approximately by the measure of water-free porosity. Deviations from the expected value of the diffusion coefficient (D) based on the measured value of water-free porosity will occur due to "trapped" air (cul-de-sac pores) in the system. The actual water-free porosity available for gas diffusion will be less than that measured by weighing and should depend also on whether the system is wetting up or drying out.

In the field measurements, soil surface crusting, non-uniform depth distribution of water and soil cracking are factors contributing to deviations from the relationship found by Penman.

In order to ascertain the contribution of trapped air in lowering the diffusion rate below calculated values, transient diffusion studies were made on sand cores over a range of moisture tensions. The results so far have shown that differences in disposition of water within the sand result in major differences in diffusion rate. With sand cores at the same moisture content by weight, different diffusion rates were obtained depending on the method by which the given water content was achieved. (The moisture contents were adjusted on a tension table.)

The results of investigations have shown that at high water contents the tortuosity factor is greater than $\sqrt{2}$ and reflects both reduction in cross-section of air space available for diffusion as well as increase in path length. Preliminary work indicates that the magnitude of the area reduction factor can be gauged from transient diffusion studies.

7. SUMMER NUTRITION OF SHEEP.

In the summer of 1954-55 the first of a series of studies was initiated to seek more precise evaluation of our sown pastures for animal production and the determination of means whereby nutritional deficiencies might be overcome.

The first study in this project is designed to determine the loss of potential growth (in terms of body size, liveweight, and wool production increment) on a good *Phalaris*-subterranean clover pasture during the first and second summer respectively of the life of the sheep. An aspect of principal importance is to study the effect of the check to growth and development on the lifetime productivity of the animal.

Replicated groups of wether weaner sheep have received the following respective treatments:

- (a) Sheep graze sown pasture without supplement;
- (b) Sheep graze sown pasture with supplement during first summer only;
- (c) Sheep graze sown pasture with supplement during the first and second summers.

During the period of supplementation there has been a wide divergence in bodyweights favouring the supplemented sheep, but during the remainder of the year (when pastures were actively growing and no supplement was given) the differences in bodyweight between the groups were greatly reduced. Supplemented sheep at their first full year's shearing cut 1.5 lb. more greasy wool than unsupplemented groups. The lifetime performance of these sheep is being studied to determine the influence of early nutrition on final size and on wool production at maturity.

A second study was commenced in the summer of 1955-56 to assess the nature of the nutritional deficiencies associated with mature pasture herbage.

Groups of grazing weaner sheep have been fed supplements containing varying levels of protein and energy with the object of determining the relative rôles of these feed constituents as factors influencing the growth of sheep grazing mature pasture herbage.

Results at the end of the first feeding period suggest that deficiencies in the summer nutritive value of these pastures are due to shortages of both these feed components.

8. INVESTIGATIONS IN CROP PHYSIOLOGY.

(a) The influence of depth of sowing, seed size and variety on the growth of subterranean clover.

The series of investigations into the growth and productivity of subterranean clover, which commenced with a study of the influence of light and temperature on growth, continued with an analysis of the effects of depth of sowing and size of seed. Initially, it was shown that the distribution of dry weight in the plant at the time of emergence through the soil and the beginning of photosynthesis was dependent on temperature and depth of sowing; but it later became apparent that depth of sowing does not affect subsequent growth, since the *area* of the cotyledons remains the same, regardless of the depth of sowing, and hence regardless of the extent to which material had been transferred from the cotyledons to the hypocotyl. Since the area of the leaves exposed to the sunlight is a major factor determining growth, depth of sowing is unlikely to be important, providing that a critical depth, determined by the size of the seed, is not exceeded. Subsequently attention was focused on seed

size, and it has been shown that production in the early vegetative phase was governed by the size of the seed. Experiments are in progress to determine for how long this effect persists in swards; it is already clear that for widely spaced plants it persists throughout the growing season. It is also evident that the early growth of three of the most important commercial strains (Bacchus Marsh, Clare and Mt. Barker) proceeds at the same rate if seed size is held constant, so that the differences between these varieties noted in the field are almost certainly due to differences in the average size of commercial seed for the particular strain.

(b) Weight changes prior to emergence of subterranean clover in relation to oxygen concentration.

Subterranean clover (Var. Bacchus Marsh) was germinated and grown for 8 days at 14° C., in the dark, in 0, 4, 14, 17, 21 and 36 per cent. oxygen in nitrogen mixtures.

There was a dependence of rate of weight change of all plant organs on oxygen concentration. The results show that seeds in 14, 17 and 21 per cent. oxygen behave in a similar manner, while those in the 36 per cent. treatment change weight at a slightly more rapid rate. There was marked depression in rate of weight change in the treatment at 4 per cent. oxygen. Germination in nitrogen did not take place in 8 days—seeds were swollen, but no extrusion of the radicle occurred.

(c) Growth of plants after oxygen pretreatment.

Using the results obtained above, staggered sowings were made so that simultaneous removal to the normal atmosphere of morphologically "identical" plants could be made from 4, 14, 17, 21 and 36 per cent. oxygen pretreatments. The time of appearance of leaf buds, part open and fully open leaves was recorded daily. The plants from lower oxygen concentrations developed at a slower rate than those from 21 per cent. and 36 per cent. pretreatments; the plants pretreated at 36 per cent. were more rapid than those in the 21 per cent. pretreatment. Rate of opening of individual leaves does not appear to limit the development of the plants during the first 30 days, but rather the rate of development of primordia during the pretreatment phase.

(d) Growth of plants in relation to soil aeration.

Subterranean clover (var. Bacchus Marsh) was grown in sand cultures with different degrees of surface sealing of the pots with a beeswax-vaseline mixture. Although adequate nutrients and water were maintained, both root weight and top weight production were dependent on the area of the soil surface available for gas diffusion.

Plant Breeding and Crop Genetics

During the past two years there have been important changes of emphasis in the current plant breeding and genetical programme. The shift has been from disease resistance in cereals to the study and improvement of cereal quality factors and to work on perennial grasses. Much of the new programme is in an early phase.

1. CEREALS.

1. *Barley*.—Barley has received relatively little attention from Australian plant breeders. It is significant that the variety in almost exclusive use in South Australia is a local selection of uncertain origin, made some 50 years ago.

Eight hundred varieties of barley were grown during the 1955 season and assessed for a large number of characteristics, such as number of tillers and ears, number of seeds per ear, 1000 grain weight, time of maturity, amount of lodging and seed shatter. The grain of several hundred of these varieties was assessed for total nitrogen content and was also used for germination tests.

The information so obtained has been used in the selection of suitable varieties for genetic and breeding studies of quality and yield factors likely to influence the breeding of improved malting and feed barleys.

2. *Wheat*.—A large collection of wheat varieties is being assembled to enable a detailed study of their morphological and physiological characteristics to be made in the light of the proposed emphasis towards quality factors. This information will be used in the selection of varieties suitable for both genetic and breeding work.

2. PERENNIAL GRASSES.

1. *Dactylis glomerata*.—Ninety strains of *Dactylis glomerata hispanica* obtained from Plant Introduction, C.S.I.R.O., Canberra, were grown in the field during 1955 and studied for characters of agronomic and genetic importance. Most of these strains had been collected in the Mediterranean area (Israel, Greece, Italy, Portugal, Morocco, Algeria and Libya) by recent collecting expeditions. Eleven strains of Northern European types of *Dactylis glomerata*, three from Great Britain, one from Sweden and seven from the United States, were also grown.

The primary object of the *Dactylis* breeding programme is to produce a perennial grass of value in the drier areas (10-20in.) of South Australia, either as a temporary ley plant in cereal districts or for use in permanent pastures. The plants, spaced at 3 × 1 feet, were scored during 1955 for such characters as tiller number, estimates of productivity, habit of growth, incidence of rust, flowering time, number of heads, seed production, dormancy during the summer and regeneration in the spring. On a basis of this scoring and with a knowledge of the collecting sites in the Mediterranean area, selections have been made for regional testing. There are indications that the development of types best adapted to the South Australian environment, particularly in respect to productivity and summer drought resistance, may involve hybridization between Mediterranean and Northern European forms. The strains showed differences in the time of flowering under Adelaide conditions. So that this should not hinder hybridization in the breeding programme, an attempt at controlling the time of flowering by artificial photoperiods was made. The seven strains studied have shown a marked difference in their response to photoperiodic induction. Other techniques associated with hybridization in *Dactylis* have also been studied.

Seed multiplication plots isolated by distance and consisting of at least 20 plants were laid down for 26 of the strains.

3. CYTOLOGY.

1. *Danthonia*.—A paper on the chromosome numbers and cytotaxonomy of *Danthonia* was completed. In co-operation with the Systematic Botanist of the Institute, chromosome counts of plants native to Australia were made for the future editions of the flora of South Australia.

2. *Barley Species*.—Chromosome counts have been made on various species of barley.

3. *Dactylis glomerata*.—In conjunction with the breeding programme of *Dactylis glomerata* a cytological examination of the material has been started. Representative plants from various localities have been studied for the chromosome behaviour at meiosis and subsequent fertility.

Previous counts of *Dactylis glomerata* have shown that the species is tetraploid. Only one case has been reported of a diploid strain, occurring in Iran. From an initial study of the Mediterranean material diploid plants have been found among a strain collected in Israel. These plants will be of value in determining some of the genetic characters of the species.

In addition, plants with the hexaploid number of chromosomes have been found in a strain from Egypt. Because of these differences from the typical tetraploid condition further study of chromosome numbers is being concentrated on collections made in the Eastern Mediterranean countries.

The relation between the chromosome number and length of stomata is being studied to assist in the selection of different chromosome races.

4. INBREEDING OF PHALARIS.

Investigation of the possible exploitation of hybrid vigour in *Phalaris tuberosa* is continuing. A range of morphological types selected as parental stock have been selfed for up to five generations, each successive generation being maintained each year by clonal propagation. Self-fertility is variable, generally extremely low and influenced by seasonal conditions. Outcrossing will probably be commenced in 1957.

5. OIL CROPS.

Oil crop investigations have been continued as a joint project of the Division of Plant Industry, C.S.I.R.O., and the Waite Institute.

In the safflower breeding programme, variability in seed emergence, early growth, oil content, yield and disease resistance have been used to develop hybrid material for the selection of drying oil varieties which combine high yield and high oil content with desirable agronomic characteristics. Hybrid material for the selection of an edible oil (low iodine number) safflower with a satisfactory yield and more desirable agronomic characters than the parent low iodine number material is also being developed.

Studies on the inheritance of low iodine number, flower colour, rust resistance and other agronomic characters were carried out as well as investigations on the germination, water relationships, and the influence of photoperiod and temperature on the development and flowering of safflower.

Linseed trials were continued with a number of varieties, selections from a cross of Punjab $\times$ Walsh, and introductions. A number of these were considerably superior in yield to the commercial variety Walsh and to the variety Punjab, and were not affected by rust under field conditions.

Agricultural Chemistry

The research activities of the department have continued to be centred on soil fertility and the study of the chemical properties of plant viruses. Much of the fertility work has been directed to a detailed study of the Seddon series of soils of Kangaroo Island and of Urrbrae loam. Some of this work has been carried out by research students working under the Colombo Plan and by a visiting Fulbright Scholar.

1. THE RESIDUAL VALUE OF SUPERPHOSPHATE.

Field experiment C95, to examine the residual value of superphosphate in a soil which had been cultivated and fertilized for 22 years, has now been in progress for 8 years and certain well-defined trends are beginning to emerge. A wheat-barley-fallow rotation is being used to measure the yield and phosphorus uptake from an area at the Waite Institute that had received a total of 24½ cwt. of superphosphate per acre since it was first cropped in 1925. The experimental site was under pasture for the 10 years prior to starting the experiment in 1947. Replicated plots, having no application of superphosphate and applications at rates equivalent to 11 lb. and 22 lb. P_2O_5 per acre at each seeding, have been established. Yield and phosphate uptake are being determined each year. This soil type is one which in its virgin state shows a well-defined response to superphosphate but, as the fertility is built up over a number of years from accumulated residues, these responses decline or disappear. The applications of 11 and 22 lb. P_2O_5 per acre were chosen to represent somewhat less and somewhat more than the average annual drain on the soil by cropping.

For the first 5 years only negligible responses were obtained to the applications of superphosphate at seeding. The accumulated residues of previously applied superphosphate were more than sufficient to maintain yields at relatively high values. However, a clearly defined increase in yield was obtained in 1953, indicating that this residual phosphate was becoming depleted. Further responses were obtained in the next two years, very marked in 1954 but less marked in 1955, possibly because of seasonal influences. It is apparent that the experiment is now entering an interesting phase. Analyses of the crops removed show that more than 80 lb. of P_2O_5 per acre (equivalent to approximately 400 lb. of superphosphate) have been removed from the control plots. As the phosphate reserve is further depleted responses may be expected under all seasonal conditions.

The mean yields of the wheat crop in the rotation for the two periods 1948-1952 and 1953-1955 were as follows:

	1948-1952 bush./acre	1953-1955 bush./acre
Control (no superphosphate)	52.0	24.8
Super. equiv. to 11 lb. P_2O_5 /acre	53.8	29.6
Super. equiv. to 22 lb. P_2O_5 /acre	54.9	36.4

Associated with the decline in the phosphate status of the experimental site there has been a marked decline in the phosphorus content of the crops. On a dry matter basis the percentage of P_2O_5 in the wheat grain has decreased from 0.7 to 0.8 per cent. P_2O_5 in the initial crops to 0.40 per cent. in 1954. Similar trends occurred in the phosphorus status of the straw. However, these steady declines were interrupted in 1955; the cause of this will need further investigation.

Another interesting feature that has emerged from this experiment is that the phosphorus content of the grain and straw is much more dependent upon the phosphorus status of the soil (and possibly seasonal conditions) than on the amount of currently applied superphosphate. The grain grown with the heavier application of superphosphate has only averaged 4.0 per cent. more phosphorus

than that of the control plots for all eight seasons, whereas during this time the phosphorus content of the grain has declined to 50 per cent. of its initial values.

Pot trials on soils from the varying treatments will shortly be desirable to confirm chemical estimates of residual available phosphorus. Nutritional experiments with P^{32} would also greatly assist in assessing the contribution of currently applied phosphate to the phosphorus status of the crop.

The balance sheet in regard to soil nitrogen in this rotation has also been examined, and it would now appear that this element is limiting the yield of barley in the rotation.

2. THE AVAILABILITY OF PHOSPHORUS IN SOILS.

Chemical extractions of soils have been further studied in order to fractionate their phosphorus compounds. Promising results have been obtained by extraction with an alkaline buffer solution in the presence of a chelating agent. Suitable analytical methods have been developed and the solubilities of a number of naturally occurring phosphatic minerals have been determined under the conditions of extraction. While further work is required before the method can be generally adopted to assess the relative phosphorus status of different soils it is proving most useful in differentiating between varying residual phosphate levels in any given soil.

The pot experiment to assess the availability and utilization of superphosphate and Rhenania phosphate in Seddon soil, in the third and fourth seasons after application has been completed. Whilst there was a steady decline in the availability each year, the response in growth to the phosphate applied in 1952 was still very marked in the fourth season. Rhenania phosphate and superphosphate gave comparable responses for equivalent amounts of P_2O_5 . However, during the four-year period only about 45 per cent. of the P_2O_5 applied to Seddon soil in this experiment was taken up and recovered in the test plant (subterranean clover), whereas, in a similar experiment with Urrbrae loam, over 65 per cent. was taken up. The decline in the availability over the four-year period was reflected in the amounts of P_2O_5 found in the clover at harvest. For the heaviest application of both phosphates the amounts found were 0.61 per cent., 0.32 per cent., 0.26 per cent. and 0.20 per cent. P_2O_5 for the four years 1952, 1953, 1954 and 1955 respectively. Due to fixation by the soil, phosphorus had clearly become the factor limiting growth during the course of this experiment.

An investigation into the retention of phosphates by soils showed that in Seddon soil reactive aluminium oxides probably contributed more than did ferric oxides to the adsorption of soluble phosphates. Phosphate so adsorbed was probably more firmly retained. The greater amounts of gibbsite in Seddon soil compared with Urrbrae loam could well account for the lower residual value of superphosphate on it.

3. OTHER FERTILITY STUDIES ON SEDDON SOIL.

Besides examining its phosphorus status, this soil has been studied in regard to deficiencies of other nutrients. At the time of the original survey the opinion was expressed that the potassium reserves were marginal and with development of the area it might become a factor limiting production. This has now been confirmed in a pot experiment in which the soil has been subjected to exhaustive cropping since 1952. In the fourth crop, in 1955, there was a clearly marked response to potassium. During the course of this experiment potassium in the

subterranean clover of the control pots (without added potassium) has declined from 1.86 per cent. K in the first season to 0.43 per cent. K in 1955. Further investigations are continuing.

Seddon soil has also been used in experimental work by a post-graduate student from Malaya, working at the Waite Institute under the Colombo Plan. He used this soil for his studies on the nutrition of rice and investigated the availability of phosphorus, nitrogen and several micro-elements under the waterlogged conditions of rice growing. The naturally occurring nitrogen compounds of the virgin soil, which are not only low in amount but also of very low availability under dry land cultivation, were found to be much more readily available under the submerged conditions of rice culture. Without applied nitrogen the yield of rice was approximately 40 per cent. of that obtainable with an optimal dressing of nitrogen, whereas with oats growing under a normal water regime the yield in the absence of applied nitrogen was only 8 per cent. of the maximum. Waterlogging did not improve the availability of the extremely small amounts of native phosphates present in this soil, but it did markedly increase the availability and uptake of phosphorus from superphosphate. Under submerged conditions rice utilized approximately 30 per cent. of the applied phosphate compared to 17 to 20 per cent. absorbed by clover at comparable rates of application.

Flooding of the soil also increased the availability of the micro-elements, manganese, copper, zinc and molybdenum. The uptake of molybdenum was greatly reduced by the application of gypsum.

4. THE SIGNIFICANCE OF NITROGEN IN VARIOUS CROP ROTATIONS.

Another post-graduate student under the Colombo Plan studied the influence of several four course rotations on the fertility and nitrogen status of Urrbrae loam and compared them with a wheat-bare fallow rotation. The plots of field experiment C53 were used for this purpose. No marked differences could be demonstrated in the total carbon or nitrogen in the soil as a result of the rotations which had been operating since 1937. However, the surface soils in those rotations which included a legume as forage crop showed the highest values for readily available nitrogen, whether determined by incubation or by acid hydrolysis. These rotations were superior to the wheat-bare fallow rotation. In general, the nitrogen was more readily mineralizable in the grazed portions of the different rotations.

Fluctuations in mineral and mineralizable nitrogen throughout the season were followed in the fallow plots of three rotations. Except when all values were extremely low because of heavy leaching during the excessively wet period of mid-winter, both mineral nitrogen and mineralizable nitrogen were higher in the rotations containing peas, particularly the grazed rotation, than in the wheat-bare fallow rotation. The mean nitrogen content of the wheat crop in the last full cycle of each rotation was found to be correlated with the available nitrogen in the soil in the autumn of 1955.

During the course of this work it was necessary to examine the optimal conditions for incubation in the laboratory and it was shown that any factor that led to loss of structure and aeration of the soil after sampling would lead to erratic results and affect nitrification adversely. Provided that structure was maintained, optimum nitrification was found to extend into a higher range of moisture contents than noted by previous workers. Consistently reproducible

results could be obtained by drying soils at 45° C. before commencing incubation tests. This avoids the adverse effects resulting from the sampling of wet soils for subsequent incubation.

5. THE AVAILABILITY OF COPPER IN COMMERCIALY PRODUCED OXIDES.

Naturally occurring oxidized ores of copper are known to be useful sources of copper for fertilizer additions. Not only are they cheaper than copper sulphate but their use in mixed fertilizers in place of the hydrated sulphate avoids certain undesirable physical properties, causing caking of superphosphate. A commercially produced oxide of copper has been evaluated as a source of available copper by means of pot experiments. On the basis of the uptake of copper by clover and oats the particular oxide was found to have only about one-half the availability of an equivalent amount of sulphate.

6. PLANT NUTRITION STUDIES.

The influence of molybdenum and sulphate on the uptake of copper by oats and subterranean clover was explored by a Fulbright Scholar from the University of California during his sabbatical leave at the Waite Institute in 1955. Oats and clover were grown in nutrient solutions at all combinations of each of three levels of sulphate, copper and molybdenum. Plants have been harvested and the project, including the analyses of the harvests for copper and molybdenum, is being completed in California.

In a subsidiary experiment the effect of the chelating agent ethylene diamine tetra acetate on the absorption and uptake of micro-elements was examined. A single addition of iron as the ethylene diamine tetra acetate complex was as efficient in providing iron to the plants and preventing chlorosis as was the weekly addition of ferrous sulphate. The chelating agent, however, had a marked effect in reducing the ionic concentrations of other micro-nutrients. Full results must await analysis but differences at the highest level of copper used (0.5 p.p.m.) were strikingly apparent. In the absence of ethylene diamine tetra acetate oats were immediately injured at this level and they made very little growth, whereas in the presence of the chelating agent there were no signs of copper toxicity or root injury and growth at this higher level of copper was equally as good as at the 0.05 p.p.m. level. Clover also showed severe root injury (indicating copper toxicity) at the higher level of copper in the absence of the chelate, whereas in its presence growth was optimal.

This experiment gave an explanation for the unexpected toxicity to oats of 0.5 p.p.m. of copper in the first experiment. This concentration of copper was known to be within the optimal range in nutrient solutions containing citrate, which is itself a weak chelating agent. The results stress the need to consider the importance of chelating agents in affecting the ionic concentrations of nutrients in all solution culture experiments used to explore the effects of balanced proportions of the micro-elements.

7. CHEMISTRY OF VIRUSES.

General.

Work on the exchange of character determinants between strains of plant viruses formed the main part of our work during the period under review, so we shall concentrate on it in this report, and give brief mention only to other phases of our programme.

Studies in the comparative metabolism of healthy and virus-infected plants have been continued, especially in relation to the fluorescent substances noted in earlier reports. One of these substances, occurring in both healthy and virus-infected tobacco leaves was identified as chlorogenic acid. Another, fluorescing yellow in ultra-violet light and not readily soluble in organic solvents, has also been investigated.

A comparison of ultra-violet absorption curves of preparations from healthy and infected plants was begun in order to get further information about what happens in the plant when virus is active.

The use of chemical reducing systems and freeze-drying of preparations as means of prolonging the time over which the virus of tomato spotted wilt could remain infective outside the living plant have been reported earlier. We have now found that storing infective plant tissue in a sealed container at the temperature of solid carbon dioxide (-69°C.) is even more effective. In one experiment the virus retained its full infectivity over a period of 21 months. This makes it possible to standardize experimental material and so to carry out experiments which would not otherwise be possible.

The preparation of pure *tobacco mosaic virus* nucleoprotein, first tested on 1st August, 1935, was still equally infective when tested 20 years after its preparation.

EXCHANGE OF DETERMINANTS BETWEEN STRAINS OF T.S.W. VIRUS.

A particular strain of a virus is characterized by the symptoms it produces on certain indicator plants. These symptoms are constant for any particular strain, given standard conditions; some symptoms may be common to a number of strains but others are diagnostic in the sense that they are the means whereby constant differences are recognized. Although generally referred to as biological symptoms, they are strictly speaking the visible expression of biochemical reactions which have taken place between virus and plant. So the cause of differences in diagnostic symptoms or characters must lie in chemical differences between the virus particles themselves.

In the previous report we reported that when a tomato plant was infected simultaneously with two strains of tomato spotted wilt (T.S.W.) virus we were able to recover from it not only the two strains originally inoculated, but other strains as well which, while differing from the originals, combined in themselves some of the characters of each. We concluded from these observations that the virus particles of the two strains exchanged determinants while they were multiplying in the plant.

Because this is the first time this phenomenon has been observed with plant viruses we thought it necessary to repeat the experiment to see whether exchange of determinants was a regular property of the virus and whether the same 'recombinants' could be isolated at will. Furthermore, in view of the far-reaching nature of the conclusions, it was considered necessary to test possible alternative explanations. The results of these experiments are summarized below:

(a) *Production of new strains of virus in vivo.*

Plants of *Nicotiana glutinosa* and of tomato which were mixedly infected with strains A and E of tomato spotted wilt virus, again gave rise to a number of strains which differed from the parent strains, A and E, but combined in themselves some of the characters of each parent. One of

these strains was related to the parent strains by the following determinant formulae:

Strain A = ABcd, strain E = abCD, new strain = aBCd, where A, B, C and D represent determinants present and a, b, c and d denote the absence of these same determinants. The new strain aBCd, recovered in 1953 from tomato plants, was in 1954 recovered also from systemically invaded leaves of *N. glutinosa*. The fact that one of the parents (A) does not invade *N. glutinosa* systemically indicates that the 'A' determinants in the new strain were incorporated at the site of inoculation.

Other new strains similar to those obtained in the earlier experiment were again isolated and are being studied. In addition, other new strains not previously seen, some of which have not been observed in nature, have been stored for future investigation.

It would seem that the phenomena being investigated are basically related to exchanges of chemical groups between nucleoprotein molecules.

(b) *Limit dilution test.*

A possible alternative explanation for the appearance of an apparently new strain is that the symptoms are caused by a mixture of parents in constant proportions. There is no evidence in favour of this, but tests were devised to get evidence for or against this possibility. The 'new' strain was purified by diluting it to near its dilution end point when only one local lesion formed per leaf or per plant. Isolates from each single lesion, when propagated, did not revert to parent type but maintained the character of the new strain. Other similar tests also resulted in evidence against the mixture possibility.

(c) *Mutation possibility.*

Although there was evidence against the alternative hypothesis that a new strain is a mutant there was a possibility of it being a mutant which is normally suppressed by one of the parents but is able to establish itself on the mixedly infected plant because the mutual interference between the parents provides a favourable opportunity. It is argued that since strain E was present in abundance in the plants in which the new strain arose, this explanation would be valid only if the new strain and strain E did not interfere markedly with each other. During the year we obtained experimental proof that the new strain and parent strain E do interfere with each other, and about to the same degree that the two parent strains do, thus ruling out this alternate explanation.

(d) *New indicator plant.*

A new indicator plant, *Datura stramonium*, has been tested, and it was found that the new strain gave a different reaction from that given by each of the parents.

It is hoped to follow up these investigations by chemical studies of the strains to seek the chemical bases of strain variation.

Plant Physiology

Research activities in Plant Physiology during the past two years fall into three main fields. The first, a physical approach to an evaluation of the factors determining transpiration from plants has been concluded following the departure of Professor F. L. Milthorpe at the end of 1954. The second, a study of growth regulators, has been continued and extended, while the third is a newly developed study on the influence of environmental factors on carbohydrate metabolism.

1. TRANSPIRATION.

The quantitative study of the rate of transpiration from plants, a programme carried out during the past 5 years, has now been concluded. Detailed investigation of a single wheat leaf as a transpiring system has allowed a full analysis of transpiration rate in terms of diffusive conductance of the stomata, wind velocity and leaf size. The study has been further extended to include evaporation from a field of wheat and the effects of the meteorological components on transpiration have been assessed. Data collected during the course of these investigations have now been collated and will be published in due course.

2. GROWTH REGULATORS.

Studies of the various phenomena involved in the elongation of plant cells have been completed. The results show that high concentrations of auxin ($\sim 1 \times 10^{-3}M$) increase the initial elongation rate of excised coleoptile sections, although this initial phase is followed by shrinkage of the sections and a loss of water and solid matter. This suggests that the long-term inhibitory effect of high auxin concentrations on growth is due to secondary responses of the tissue and not to an immediate retardation of the growth processes. This work has now been submitted for publication.

The relationship between expansion in cell wall surface and uptake of water was investigated by using the effects of high concentrations of auxin (referred to above) and also by controlling water movement into the cells with solutions of sucrose and mannitol. The results do not support the theory that the main effect of auxin is to induce water uptake, with the wall expanding as a consequence of increased hydrostatic pressure within the cell. They can be better explained by the concept of water entry as a movement along a gradient produced by an increase in the diffusion pressure deficit of the cell resulting from metabolically controlled synthesis of new cell wall material. These results are now being prepared for publication.

Investigations have begun on the physiological behaviour and possible methods of control of soursob (*Oxalis pes-caprae*), an important weed in South Australia. Studies thus far have been mainly concerned with factors, especially the application of growth regulators, influencing the formation of bulbs and tubers. It has been shown that whereas some of these substances decrease the number of bulbs per plant, others lead to an increase. Furthermore, it appears that this response can be changed by altering the time of application of the growth regulator and more information on this aspect is being sought.

It is known that soursob resists the action of moderately high concentrations of auxins but the nature of this resistance is not yet understood. It has been

shown, however, that detached leaves possess a mechanism which inactivates Indole Acetic Acid and that this response depends upon temperature, inactivation being greater at higher temperatures. The possibility that a similar mechanism may operate with other growth regulators (e.g. 2, 4-D) is being explored. There are also indications that a growth inhibiting substance is present in the outer bulb scales, and studies directed towards elucidating the importance of this substance in dormancy are in progress. Other experiments on the dormancy of soursob bulbs have produced evidence that the controlling environmental factor is temperature, while the availability or non-availability of water is of little importance. In cool temperatures bulbs germinate within three months of the death of the tops, and this finding has considerably facilitated experimental procedure as plants can now be grown almost throughout the year. A method of culture which has proved useful in studying the manner of spread of bulbs is that of growing a single plant in a glass tube containing soil. In this way it was observed that soursob tubers when shrinking make a tunnel through the soil and that later the bulbs are drawn downwards through this hole. Thus a considerable vertical distribution (~ 2 ft.) is achieved.

Studies on the growth of the weed under field conditions are also being carried out. Hormones which have shown the most promising results for control purposes are now being tested on mixed associations of soursob, and either wheat or subterranean clover. It is necessary to continue this work for several years to assess cumulative effects on bulb formation and subsequent establishment.

3. METABOLISM.

A new project on the influence of environmental factors on starch and sugar metabolism has begun. Although the overall effect of these factors on the carbohydrate system is known, knowledge of the way in which such factors operate is lacking. The aim of the present investigation is to provide such detailed information, and as a first approach the relationship between nitrogen nutrition and starch synthesizing ability, and also physiological age and starch synthesis, is being studied. Preliminary results using barley grain suggest that the absolute amounts of the enzymes responsible for starch synthesis and degradation vary in relation to nitrogen treatment. However, it is well known that plants grown under high nitrogen conditions have low carbohydrate concentrations while the reverse is true of plants grown at low nitrogen levels. It follows, then, that the absolute amounts of starch synthesizing and degrading enzymes do not alone determine the final amount of carbohydrate synthesized. During maturation of the grain the ratio of synthesizing to degrading enzymes appears to change in favour of the latter. Further information on the underlying mechanisms of these inter-relationships is still required since this should lead to a fuller understanding of the mechanisms controlling starch synthesis and degradation in grain.

The respiration of detached tobacco leaves under controlled conditions has been examined. This data will allow the correlation between respiratory rate and concentration of any specific sugar to be determined. To ensure a wide range of sugar concentrations leaves were subjected to either shading which reduces sugar content, or sugar feeding which increases the amount present. From results obtained so far respiration appears to be uniform in leaves of widely different sugar content, thus confirming earlier results. No evidence of significant bacterial action was detected under the conditions used.

4. NUTRITION.

Collaborative work with the Commonwealth Scientific and Industrial Research Organization has begun in this field. Tobacco plants have been grown at different nitrogen and potassium levels in sand culture and leaf samples taken at regular intervals for analysis and curing. At high nitrogen levels, the potassium treatments produced deficiency symptoms varying in intensity with the potassium level used. However, at the low nitrogen levels the different potassium treatments did not produce any visual symptoms. The appearance of the leaves after curing was also clearly related to the nutritional levels applied and the effect of nitrogen deficiency on appearance of cured leaves was distinctly different from that of potassium. In order that carbohydrates and amino-acids in the leaf could be correlated with the appearance of the cured product, the half leaf technique was used for harvesting. It has been known for some time that half leaves cure satisfactorily only if the midrib is left attached. For this reason the leaves were cut along their length to one side of the midrib, the half containing the midrib was cured in a specially constructed cabinet while the remainder was dried in an oven with forced ventilation at 65° C. Analysis of the carbohydrates and amino-acids in the latter samples is now being carried out.

The respiratory rates of tobacco leaves have also been determined under conditions similar to those operative during curing. These will permit estimation of the carbohydrate lost during this process and also of the amount of oxygen consumed. Further, the respiration of leaves from plants grown at different nutritional levels, and also from plants subjected to shading, was examined. These results may have important implications in commercial practice and, moreover, will provide information on the underlying mechanisms controlling the changes occurring in curing.

Entomology

During the two years under review, the programme of investigations on pasture insects was continued. New fields of investigation included the entomological problems of lucerne, and a study of aphid physiology, with particular reference to the dispersal of the winged forms.

A textbook on animal ecology, written by H. G. Andrewartha in joint authorship with L. C. Birch of the University of Sydney, was completed and published by the University of Chicago Press. It is entitled "The Distribution and Abundance of Animals".

Advisory services in entomology were provided to official departments, including the Department of Agriculture, Department of Woods and Forests, the Department of Health, and to the Deputy Director of Plant Quarantine.

1. INSECT PESTS OF PERMANENT PASTURES.

A comprehensive study of the ecology of the underground grass grub (*Oncopera fasciculata* Walker), which had been in progress during the past five years, was completed, and the programme terminated.

Details of the investigation have been given in previous reports in this series. The work has given a clear picture of the biology of the insect, and has established the factors which combine to produce plagues in particular years. *O. fasciculata* occurs in South Australia only in the extreme south-eastern

corner (county Grey) where it is a native inhabitant, and permanently established. It has one generation each year; the caterpillars are destructive to pasture, but damage is not serious unless populations of the order of 6-10 individuals per square foot are present. In a year of favourable spring rainfall (providing favourably moist conditions as the eggs are hatching) there may be a high survival of young caterpillars; on the other hand, dry conditions at this time result in heavy mortality. In autumn and winter the burrowing caterpillars may be drowned by heavy rains and high soil watertables. Rank pasture growth in spring favours survival of young caterpillars, and there is evidence that pastures well-grazed or mown in September-October are less likely to be damaged than those which remain tall and dense.

A number of papers are in preparation in which the research findings are set out, and a detailed discussion is given of the measures that may be taken by the landholder to limit *Oncopera* damage. Control by insecticides has been shown to be practicable and economically justified, and methods of land-management are discussed by which the risk of plagues is diminished.

Further studies were made on the biology and field behaviour of the pasture cockchafer (*Aphodius howitti* Hope), as part of a programme of research upon this insect, which is widely distributed in the wetter parts of the State, from the South-East to Eyre's Peninsula. It is an important pasture pest, especially in pastures dominated by annual herbage plants. The habits and ovipositional preferences of the adult beetles were worked out. The beetles lay their eggs in burrows dug in the soil; it has been shown that soils of equivalent pF status are selected. A study was made of the survival of the larvae in places where they might live. The ability of larvae to tolerate flooding, and of the prepupae to withstand water-loss, were also investigated.

A field trial with insecticides demonstrated that larvae can be controlled economically on a field scale; residual effects in the second and third years will be examined.

2. ENTOMOLOGICAL PROBLEMS OF FIELD CROPS.

The field biology of the armyworm, *Persectania ewingii* Westw., has been further studied. This insect is a major pest of cereal crops and grassland in South Australia; it is a native insect, and reaches plague numbers at irregular intervals. It has been shown that two kinds of larval behaviour are exhibited. In years when conditions (rainfall, low winter temperatures) do not favour swarming, the larvae are solitary, inert, and pale in colour. When conditions are favourable, and a high population density is reached, larvae are developed which are irritable, swarming, and migratory, and deeply pigmented. The micro-anatomy and ontogeny of the integument, and aspects of the physiology of the two larval forms are being studied in an effort to explain the basis of their differences. A study of the natural enemies of these caterpillars shows that a large variety of parasitic and predatory insects attack them, and a granulosis-type virus disease was also shown to cause severe mortality in certain circumstances.

The biology and ecology of *Agrotis infusa* Boisd. is also under investigation. The caterpillar of this moth is a cutworm, which under South Australian conditions may be quite scarce, or may infrequently reach very large numbers. It feeds on a variety of legumes, including medics. A study has been commenced of the life-history, food plants, and seasonal incidence of this species under local conditions.

Lucerne is attacked by a complex of insects and mites, some of which reduce significantly the yield of herbage and of seed where the crop is grown for seed production. During the past two years a pod-boring caterpillar came under notice; it caused severe loss of seed in the Keith-Tintinara district, and has been identified as *Etiella behrii* Zell., a native pyralid which had not previously been reported as a pest of lucerne. A programme of research has been initiated to study the various insects affecting lucerne, and to determine their relative importance; the ecology of *Etiella* is being given precedence at this stage.

3. INSECTS OF HORTICULTURAL CROPS.

A study of the scale insects has been in progress for several years, and during the period under review a comprehensive bibliographic index of the described Australian species has been completed. A survey of the mealybugs has been continued, and information has been obtained about the species occurring in South Australia, and upon their host plants and biology. A list of the species of exotic Coccoidea known to be naturalized in the State is being prepared for publication.

During the past two years some preliminary studies have been made upon a reported occurrence of DDT-resistant population of codling moth in the apple-growing district of Paracombe, near Adelaide. Laboratory studies showed that the insects, both as adults and as larvae, were highly resistant to DDT solutions directly applied to them. They were, however, susceptible to thiophosphate insecticides such as malathion, which gave effective control in orchard trials conducted by the Department of Agriculture. Further more detailed investigations are contemplated.

An investigation upon the biology of the vine phylloxera was continued at Rutherglen in Victoria, where this insect is permanently established. The scope and early results of the work were outlined in a previous report; the incidence of leaf galls on hybrid American vines has been studied in greater detail, and the complete life cycle on both European and American vines has been worked out.

The mealybug *Pseudococcus adonidum* L. is a long-standing problem of oranges grown under irrigation at Waikerie and other localities along the Murray River Valley. The insects become localized in the navel end of ripe fruit, and cause blemishes and storage failures which result from honey dew and the sooty moulds which grow in it. An investigation of the ecological factors determining the incidence of mealybugs with respect to such matters as size of tree, closeness of planting, influence of cover crops and adjacent types of planting upon populations of predators, was commenced during the period under review.

4. OTHER INVESTIGATIONS.

Marked differences have been noted in the performance of the beetle, *Chrysomela quadrigemina* Suffr. in controlling the weed, *Hypericum perforatum* (St. John's Wort), under South Australian conditions. In an open arable environment (Yankalilla), virtual extinction of the weed has been produced; in woodland conditions (Clare, Belair) results have been poor or negligible. The beetles spend the summer (November to March inclusive) in aestivation. In wooded situations they shelter in masses beneath loose bark; the trunks of eucalypts, which carry much loose bark, offer particularly favourable situations for the beetles. In such places they are subject to heavy predation by the permanent population of bark-living spiders and other predatory arthropods; evidence ob-

tained indicates that the intensity of predation is a significant factor in maintaining beetle populations at ineffective levels in wooded areas. In open situations the beetles aestivate in litter on the soil surface and are less subject to predation.

A Robinson mercury-vapour light-trap was set up at the Waite Institute in 1955 and has been maintained continuously since that time. The catch (principally Lepidoptera) is being sorted and analysed. It has provided valuable information about the periodicity and seasonal incidence of many species about which little was previously known. An account of this work is in preparation.

Plant Pathology

I. GENERAL ADVISORY WORK.

The plant diseases recorded in previous reports continue to give trouble to agriculturists and horticulturists in South Australia, but specimens submitted by the Department of Agriculture and observations made during field tours indicate from time to time that their relative importance and geographic distribution show considerable changes, the most important of which are mentioned below.

Cereals. Eelworm (nematode) attack has continued to be important on oats in the Keith-Bordertown area, but has recently been observed to cause appreciable economic loss on this crop in the Upper Eyre Peninsula, where also the loose smut (*Ustilago avenae*) has also increased in importance on the same crop. In this same area frost in 1955 at a critical period in the development of the wheat crop caused abortion of the spikelets, an unusual occurrence in South Australia, though frequently encountered in parts of New South Wales. In the mid-North areas, during the wet winter of 1955 the young wheat suffered considerably from "unthriftiness", chlorosis and root-rotting; no definite causes were discovered for these troubles, but fortunately most crops recovered satisfactorily during the spring.

Subterranean Clover. Infection by *Physoderma* (*Urophlyctis*) *alfalfae*, causing galls on the stems, leaves and inflorescences, was found to be more widespread in South Australia during the wet winter of 1955 than had previously been thought, and this disease is now under more detailed investigation.

Lucerne. Downy mildew (*Peronospora trifoliorum*) and rust (*Uromyces striatus*) appear to have become more severe in their attack during the period under review, and have caused significant reductions in yield of fodder; Black Spot (*Pseudopeziza medicaginis*) has also been common, but in general is less important in effect.

Vegetables. Glass-house tomatoes still suffer serious loss from *Verticillium* wilt and from the attack of the root-knot eelworm; though soil fumigation usually provides a fair measure of control, reports have been received that in a number of cases fumigation efficiently carried out has proved ineffective. *Fusarium* wilt of peas has increased in importance, especially in some of the newer irrigation settlements; in co-operation with the Department of Agriculture work is now in progress on the introduction and testing under local conditions of varieties reported as resistant to *Fusarium* in other countries. Bacterial blight of peas (*Pseudomonas pisi*) is of scattered occurrence, but local attacks can be severe, especially following hail or frost damage to the plants; available evidence indi-

cates that this disease may be soil-borne. The attack of *Sclerotinia* on a number of vegetable crops continues to be a serious problem in certain areas.

354 *Orchard Crops.* Eelworm diseases, particularly root-knot (*Meloidogyne* spp.), in stone fruits and vines are causing serious concern in the irrigated areas. During the past two seasons apricots and peaches have shown a breakdown of the tissues around the stone of the fruit, causing serious losses to growers in the irrigated areas; no pathogenic fungus or bacterium has been found associated with the early stages of this breakdown. What appears to be the "ring pox" virus of apricots, as judged by symptomatic appearance, was observed on one orchard at Berri and another at Sandy Creek; in both cases the growers decided to remove and burn the affected trees. The virus complex known as "infectious degeneration" appears to be common in vines in South Australia, and symptoms closely resembling bacterial blight (*Erwinia vitivora*) have been seen in several areas; both these diseases are now under investigation, in co-operation with the Department of Agriculture. In both years under review 3 Downy Mildew (*Plasmopara viticola*) appeared early in the season; immediate spraying of vines, combined with spells of weather unfavourable to the spread of the fungus, averted serious general outbreaks. Bacterial blight of pears and stone fruits (*Pseudomonas syringae*) was serious in orchards in the Adelaide Hills area in 1954, and preliminary investigations on the disease have been carried out.

Ornamentals. Losses from attack by *Botrytis gladioli* on flowers of *Gladiolus* in parts of the Adelaide area were serious. "Tulip fire" caused by *Botrytis tulipae* was serious in 1955 on one property in the Adelaide Hills; this is the first record of this disease in Australia. Virus diseases of dahlias are now so widespread that growers will need to give serious attention to production and maintenance of virus-free stocks.

2. PLANT QUARANTINE.

Regular inspections of plants imported from overseas and growing under quarantine in various nurseries were continued in collaboration with the Department of Agriculture. A number of diseases, mainly of virus nature, were thus intercepted, and infected material destroyed.

3. RESEARCH ACTIVITIES.

Rhizoctonia Investigations.

256 Taxonomic studies on the different pathogenic strains of *Rhizoctonia* have been completed. One strain, causing "damping off" in a wide range of vegetable seedlings at temperatures above 20° C. was separated as a distinct species, *Pellicularia praticola*; all other strains, including that causing "bare patch disease" of cereals and pastures, belong to a second species, *Pellicularia filamentosa*.

The process of penetration and stages at which strain specialization occurs are now clearly defined, but there is no precise information on the nature of the factors governing the latter. One of the two important stages is the attachment of the fungus hyphae to the host and formation of appressorial structures prior to penetration; further indirect information supports the hypothesis of a chemical stimulus being important at this stage. An empirical, but more direct, approach is being used to test this hypothesis, by the coating of the cuticle of the stem of the host with various materials to determine whether they influence attachment and appressorial formation. Stem-attacking strains formerly regarded as

specific to one host family have now been shown to be capable of attacking the leaves and petioles, but not the stems, of hosts of other families. The use of membranes, particularly of cellophane, for separating the host and pathogen in inoculated soil, as described in earlier reports, showed that the roots of various seedlings stimulated only those strains of the fungus capable of attacking them, but there is no direct evidence that this root stimulation is related to the selective pathogenicity of the strains. This study is being extended to a wider range of strains of the fungus.

In the field a new strain of *P. filamentosa* capable of attacking coleoptiles of germinating cereals was isolated. This caused some losses in several individual crops over the last two years, as it occurred generally over the fields, and not in localized patches. "Bare patches" in cereal crops caused by the more common root strain of *P. filamentosa* were mapped over three seasons. The patches remained in the same places each year, but increased in diameter by 1-5 feet each season; a few disappeared completely each year, and approximately a corresponding number of new ones appeared, leaving the total number more or less constant. There is some evidence that the fungus can be spread in wind-blown soil. Hitherto experiments on time and type of cultivation, fertilizer treatments and crop management on the incidence of the "bare patches" have yielded no differential effects, but the trials are not yet complete.

"Blind Seed" Disease of Rye-Grass.

This disease, caused by *Phialea temulenta*, has been recorded from Victoria and Tasmania, though not previously from South Australia, though seed samples from the South-East have germinated poorly in recent years. Investigation has shown that this seed is frequently infected by *Phialea*, whereas seed from the mid-North areas was only occasionally infected, and then not very severely.

Ascochyta Stem Rot of Peas.

Both field and garden peas show a stem rotting, and garden peas also a severe spotting of leaves and pods, caused by *Ascochyta pinodella* and by *Mycosphaerella pinodes*, and these diseases recur almost every year in South Australia. In the case of garden peas severe losses frequently occur. Studies have shown that these fungi are not commonly carried on local seed, but there is strong evidence that they are soil-borne; seed planted in sterilized soil has shown no sign of infection, whereas duplicate seed samples planted in untreated soil became infected. *A. pinodella* is suspected of occurring in soil which has never previously grown peas.

Virus Investigations.

Studies of virus diseases of stone fruits have been continued. A latent virus disease of cherries has been found to be very widespread, but of importance on only three local seedling varieties, in which it induces a severe necrosis. The symptoms resemble those described in U.S.A. for Lambert Mottle, and inoculations to the variety Lambert have recently been made. Two other virus diseases of cherries, resembling Black Canker and Tatter-Leaf, have also been found widespread here. Local plums appear to be very commonly infected with a mosaic line-pattern disease, but this is of little economic importance. Recently three peach trees of the varieties J. H. Hale and Early Crawford were found infected with Peach Wart, a disease not previously reported in Australia. All these diseases have been transmitted to young seedlings of peach, apricot and cherry; it is hoped to use a similar technique to select virus-free

stocks of all varieties of stone fruits, and thus to develop a system of certification for these crops.

Work on seed transmission of virus diseases is now approaching completion; it has been found that virus-induced sterility in plants cannot account for the lack of seed transmission of those viruses tested in this work. Experiments on embryo-culture have consistently failed to reveal any virus-inactivation by developing embryos. Present work is aimed at determination of the factors concerned in seed transmission of common bean mosaic. For the moment it is concluded that the rarity of seed transmission is the result of two factors: first, the inability of the virus to infect the gametophytic cells of the host, and secondly, its inability to infect the developing embryo, because of the lack of protoplasmic connection through plasmodesmata with the surrounding tissues, and also of the lack of vascular connection between the embryo and the parent tissues.

Studies on the Microflora of Australian Soils.

Detailed investigation of the occurrence and activity of fungi in a wheat-field at the Waite Institute has been undertaken; results show that the advent of the wet season and the ploughing-in of plant residues are the major factors affecting the activity of fungi in this soil. Some species appear to have relatively short periods of growth in the soil, and to survive as spores for the remainder of the year, while other species appear to be present as mycelium throughout the year. Several parasitic fungi have been isolated from soil of this field, and information is being sought on their growth and survival in soil and on their effect on the crop.

Fungal Gummosis of Apricot.

The investigation mentioned in the previous report has continued with the following results:

832 (a) A systematic search of dead apricot wood finally revealed a species of *Eutypa* that was capable of causing typical gummosis symptoms when inoculated into apricot limbs; in culture this fungus is identical with the *Cytosporina* regarded as the cause of the disease. The *Eutypa* perithecia do not appear until about 5 years after a branch has died from gummosis, but these perithecia appear to be capable of producing successive crops of ascospores for several seasons after their first formation. Perithecia have been found wherever the disease occurs in South Australia, Victoria and Tasmania, but are rare in districts with a rainfall of less than 13 inches per annum. The cool, moist climate of the Hobart district of Tasmania appears most favourable for the development of this stage of the life-cycle. Ascospore discharge occurs whenever sufficient rain falls to wet the perithecia thoroughly, and ejected spores remain viable for up to 10 weeks, thus being well adapted for wind dispersal over long distances.

(b) A collection of several hundred seedlings is now growing in the glass-houses of the Waite Institute, and are now under test for susceptibility to ascospore infection.

(c) Preliminary observations indicate that most infections occur during the spring months of September to November. Though there is ample moisture for ascospore discharge during the winter months, it is considered that the low temperatures at this season limit infection. Further work on modifications of pruning systems as an aid to field control of the disease has been undertaken by the officers of the Department of Agriculture.

(d) It is now considered that a State-wide effort to destroy sources of inoculum and to improve orchard hygiene should prove of great benefit in obtaining satisfactory control of this disease.

Mycology.

The compilation of records of Australian Fungi has been continued, and a number of enthusiastic collectors has been recruited in various parts of Australia. It is noteworthy that their collections have resulted in a large number of new records and new species for the Australian Flora, so that it is increasingly evident that hitherto only the fringe of this subject has been touched here. An instance of this is afforded by the flora of living and dead leaves and twigs of *Eucalyptus* spp.; so far it is rather rare to obtain duplicates of fungi already recorded on these and almost every specimen contains a new species. During a period of study leave in England in 1954-55, Dr. Hansford examined a large number of the original specimens studied by Cooke and Massee; many of these were found not to correspond with the names and descriptions given by these workers. This has led to further confusion, as later authors have assigned their specimens to the species described by Cooke and Massee, so that it now becomes necessary to re-examine these later collections and to revise their nomenclature in the light of the results obtained at Kew. Meanwhile, all new species discovered, and the more important revisions, are being published annually for the benefit of other workers in Australia.

Work on the monograph of the genus *Meliola* has progressed, and at present almost the only large world collection now awaiting revision is that of F. L. Stevens, now on its way here. It is hoped to prepare the final work for printing at the end of 1957.

Professor J. B. Cleland has generously donated his mycological herbarium to this Department, and so far over 2,300 specimens have been incorporated into our herbarium.

4. LEGUME SEED INOCULATION.

During the past two years the demand for bacterial cultures of *Rhizobium* decreased considerably, as proprietary peat inoculants became available here. It was noted with concern that many of these proved unsatisfactory in field trials in 1954, but the 1955 trials showed marked improvement. In field trials on virgin soils, marked responses in the growth of lucerne, field peas, and blue lupins of both West Australian and New Zealand origin, have been obtained after seed inoculation with effective strains of *Rhizobium*. Evidence of the necessity for seed inoculation of subterranean clover proved less clear-cut; in most areas tested little or no response to inoculation was obtained, but a marked response was found in one locality.

Meteorological Records

Meteorological observations in connection with the work of the Waite Institute are being made at two centres: at the Waite Institute itself and at Yudnapinna (north-west of Port Augusta). Observations are made at 0900 local time.

The records for 1954 and 1955, together with climatological summaries, are given for both centres in the following tables.

RECORDS AT THE WAITE INSTITUTE

(34° 58' S., 138° 38' E. Height 402 ft.)

I. Monthly rainfall and evaporation (in.), number of rainy days and relative humidity, for 1954 and 1955, Waite Institute.

Month	Rainfall		Number of days with $\geq .01''$ rain		Evaporation		Relative Humidity (0900 local time)	
	1954	1955	1954	1955	1954	1955	1954	1955
January	0.74	0.08	4	3	9.05	9.60	47	43
February	0.01	2.44	1	6	6.73	6.41	52	55
March	0.50	0.16	3	3	5.98	5.76	50	55
April	4.80	1.49	9	11	4.22	4.24	57	54
May	1.14	5.76	13	18	2.39	2.33	66	70
June	3.60	6.94	17	19	1.57	1.65	78	78
July	2.74	2.66	17	17	1.60	1.56	76	80
August	1.52	3.90	12	21	2.25	2.37	73	72
September	1.06	1.60	11	12	3.70	3.29	56	59
October	2.08	2.30	12	12	4.51	4.58	57	58
November	0.84	2.64	9	14	5.89	5.26	50	56
December	1.67	1.26	3	7	8.15	7.73	48	45
Year	20.70	31.23	111	143	56.04	54.78	59	60

II. Mean of daily air temperatures (°F) for 1954 and 1955, Waite Institute.

Month	Maximum		Minimum		Mean $\frac{1}{2}(\text{Max.} + \text{Min.})$	
	1954	1955	1954	1955	1954	1955
January	81.6	84.8	63.3	64.0	72.5	74.4
February	76.3	82.6	55.5	64.1	65.9	73.3
March	75.1	77.2	55.5	59.8	65.3	68.5
April	72.3	71.4	57.5	55.3	64.9	63.4
May	63.5	60.8	51.6	48.1	57.5	54.4
June	58.0	58.5	47.7	48.6	52.8	53.6
July	58.2	56.3	45.8	45.7	52.0	51.0
August	60.2	60.2	45.9	47.8	53.1	54.0
September	64.5	66.5	49.9	50.2	57.2	58.4
October	68.1	68.1	52.6	52.0	60.4	60.0
November	74.0	69.4	54.3	52.4	64.2	60.9
December	80.5	74.9	59.8	57.0	70.1	65.9
Year	69.4	69.2	53.3	53.8	61.3	61.5

III. Mean of daily soil temperatures (°F) at 1 inch, 6 inches, 12 inches and 24 inches for 1954 and 1955, Waite Institute.

Month	1 in. Maximum		1 in. Minimum		6 in. Maximum		6 in. Minimum	
	1954	1955	1954	1955	1954	1955	1954	1955
January	105.4	107.6	63.7	65.3	82.8	86.6	71.2	73.0
February	101.8	100.3	59.3	64.6	80.0	84.4	67.9	71.4
March	92.7	93.3	56.6	60.7	74.7	78.1	64.1	67.2
April	78.9	79.8	55.4	54.1	68.3	68.4	61.5	60.3
May	65.1	64.9	50.2	48.1	59.4	58.3	55.1	52.9
June	59.3	61.5	46.8	47.3	54.9	55.9	51.3	51.5
July	61.2	60.1	43.9	44.9	54.1	53.7	48.6	49.1
August	63.8	63.2	44.6	46.1	55.9	55.9	49.7	50.4
September	74.9	77.3	48.1	49.6	63.0	64.2	53.6	55.1
October	80.4	79.1	52.9	53.6	68.1	67.6	58.6	58.8
November	92.4	81.3	56.7	55.6	76.3	69.9	63.2	60.4
December	102.1	91.7	62.3	61.0	84.0	77.7	69.1	66.7
Year	81.5	80.0	53.4	54.2	68.5	68.4	59.5	59.7

Month	12 in. Maximum		12 in. Minimum		24 in. Maximum		24 in. Minimum	
	1954	1955	1954	1955	1954	1955	1954	1955
January	76.6	79.6	72.7	74.9	70.9	73.1	70.2	72.3
February	73.8	78.6	70.0	74.0	69.2	73.3	68.7	72.4
March	69.5	72.9	66.3	69.6	66.3	69.3	65.8	68.7
April	65.6	65.5	63.2	63.1	63.8	64.2	63.1	63.8
May	57.7	56.5	56.5	54.8	57.7	56.5	57.3	56.0
June	53.7	54.2	52.5	52.9	54.0	54.2	53.7	53.7
July	51.5	51.5	49.9	50.3	51.2	51.4	50.9	51.1
August	52.9	53.2	51.0	51.6	52.0	52.3	51.6	52.0
September	57.8	59.6	55.0	56.8	55.0	56.5	54.4	55.9
October	63.3	63.3	60.2	60.5	59.8	59.9	59.2	59.3
November	69.5	65.5	65.0	62.2	63.8	61.6	63.1	60.8
December	76.1	72.2	71.0	68.4	69.2	68.3	68.5	67.4
Year	64.0	64.4	61.1	61.6	61.1	61.7	60.5	61.1

IV. Mean wind velocity at 1.25 metres and 2 metres from the ground (in miles per day) from cup anemometers for 1954 and 1955, Waite Institute.

Month	1.25 Metres		2 Metres	
	1954	1955	1954	1955
January	94	91	106	107
February	88	81	98	96
March	81	78	89	92
April	71	71	83	84
May	55	75	71	89
June	56	74	72	90
July	60	61	76	77
August	64	106	80	127
September	70	66	86	81
October	76	82	92	102
November	77	77	93	93
December	83	89	98	105
Year	73	79	87	95

GENERAL CLIMATOLOGICAL DATA.

The most important data on which are based studies of climatology as applied to agriculture and biology involve rainfall, evaporation, temperature and humidity.

Evaporation from a free water surface is dependent on temperature, humidity, sunshine and wind. Estimates of evaporation have usually been made in the work of the Waite Institute on the assumption that it is proportional to saturation deficit when comparisons made for two or more localities relate to the same month. The ratios of precipitation (rain, hail, snow and dew) to evaporation or saturation deficit have been found of special value in agro-climatological studies. A ratio of more universal application has been found to be that of precipitation to the 0.75^{th} power of evaporation or atmospheric saturation deficit, and this ratio is being increasingly applied and tested. It can be assumed that monthly values of $1.2E^{.75}$ or $12 \text{ s.d.}^{.75}$ correspond closely to the evaporation from a vegetated land surface with adequate but not over-abundant soil moisture. For drought-resistant crops at the lowest level of production the value is closer to $0.8E^{.75}$.

V. Climatological data for the Waite Institute. Means of 31 years, 1925-55.

Month	Rainfall inches	Evapora- tion inches	Number of days with $0.01''$ rain	Relative humidity per cent.	Hours of bright sunshine per day	Air temperature °F		
						Max.	Min.	Mean
January	0.95	8.66	5.1	48	8.9	81.7	60.6	71.1
February	1.15	6.98	5.3	52	8.6	80.6	60.5	70.5
March	0.78	6.42	5.2	51	7.7	78.3	59.3	68.8
April	2.10	3.98	11.4	61	5.6	70.2	54.4	62.3
May	3.12	2.65	13.8	68	4.1	64.0	50.6	57.3
June	3.12	1.72	15.3	75	3.2	58.7	46.7	52.7
July	3.18	1.73	17.6	75	3.2	57.3	45.3	51.3
August	3.00	2.28	16.6	71	4.4	59.1	45.9	52.5
September	2.35	3.25	13.4	64	5.7	64.0	48.3	56.1
October	2.21	4.57	12.4	60	6.5	68.2	50.9	59.5
November	1.60	6.03	9.1	54	7.7	73.6	54.5	64.0
December	1.21	7.76	6.6	49	8.3	78.8	57.9	68.3
Year	24.77	56.03	131.8	61	6.2	69.5	52.9	61.2

VI. Climatological data for the Waite Institute. Means of 31 years, 1925-55 corrected to a standard month of 30.4 days.

Month	Rainfall inches	Evaporation (E) inches	Saturation deficit (inches of mercury)	Water need of vegetation		
				low $0.8 E^{.75}$ inches	moderate $1.2 E^{.75}$ inches	high $1.6 E^{.75}$ inches
January	0.93	8.49	.420	3.98	5.97	7.96
February	1.24	7.51	.373	3.63	5.44	7.26
March	0.77	6.30	.379	3.18	4.77	6.36
April	2.12	4.03	.223	2.28	3.41	4.55
May	3.06	2.60	.155	1.64	2.46	3.28
June	3.16	1.74	.099	1.21	1.82	2.42
July	3.12	1.70	.093	1.19	1.79	2.38
August	2.94	2.24	.117	1.46	2.20	2.93
September	2.38	3.29	.175	1.95	2.93	3.91
October	2.17	4.48	.219	2.46	3.69	4.93
November	1.63	6.11	.296	3.11	4.66	6.22
December	1.19	7.61	.379	3.67	5.50	7.33
Year	24.71	56.10	.244	29.76	44.64	59.53

VII. Soil temperatures ($^{\circ}\text{F}$) at the Waite Institute. Means of 31 years, 1925-1955.

Month	1 in.		6 in.		12 in.		24 in.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	108.9	64.0	85.4	71.4	78.2	73.0	73.4	71.4
February	105.7	63.5	84.1	70.8	77.7	72.7	73.8	71.9
March	99.8	61.1	79.8	68.0	74.7	70.1	71.9	70.0
April	81.9	54.8	69.0	60.5	66.6	63.4	66.4	64.6
May	69.3	49.9	60.7	54.5	59.8	57.4	60.9	59.3
June	62.5	46.5	55.2	50.3	54.8	52.8	55.9	54.7
July	60.8	45.2	53.5	48.5	52.8	50.7	53.6	52.4
August	64.2	46.2	55.8	49.9	54.1	52.0	54.1	52.8
September	73.3	49.4	62.0	53.8	58.7	55.5	57.2	55.7
October	82.7	53.6	68.8	58.5	64.0	60.2	61.5	59.8
November	93.7	58.4	76.4	63.9	69.9	65.3	66.2	64.2
December	103.5	62.3	82.5	68.8	75.1	70.1	70.7	68.6
Year	83.9	54.6	69.4	59.9	65.5	61.9	63.8	62.1

RECORDS AT YUDNAPINNA

(32° 8' S., 137° 10' E.)

VIII. Monthly rainfall (in.), number of days with ≥ 0.01 inches of rain, and relative humidity for 1954 and 1955, Yudnapinna.

Month	Rainfall		Number of days with ≥ 0.01 inches of rain		Relative humidity (0900 local time)	
	1954	1955	1954	1955	1954	1955
January	1.29	0.00	2	0	44	38
February	0.05	0.60	1	4	54	49
March	Trace	1.99	0	7	54	58
April	3.51	0.47	8	3	62	56
May	0.07	1.39	3	9	70	70
June	1.57	0.94	8	16	82	78
July	0.27	0.91	3	9	80	82
August	0.92	1.97	4	13	68	72
September	0.17	0.73	3	8	55	54
October	1.24	0.29	7	6	65	44
November	0.53	1.12	7	7	38	45
December	0.64	0.00	4	0	42	41
Year	10.26	10.41	50	82	60	57

IX. Mean of daily air temperatures ($^{\circ}$ F) for 1954 and 1955, Yudnapinna.

Month	Maximum		Minimum		Mean $\frac{1}{2}$ (Max. and Min.)	
	1954	1955	1954	1955	1954	1955
January	91.1	94.0	65.5	66.1	78.3	80.0
February	86.2	91.9	59.8	67.6	73.0	79.8
March	86.7	82.6	53.7	62.0	70.2	72.3
April	76.9	74.9	53.3	53.7	65.1	64.3
May	68.7	64.7	44.1	46.6	56.4	55.6
June	61.7	60.9	40.4	51.0	51.1	56.0
July	63.0	59.3	36.0	40.5	49.5	49.9
August	67.0	65.1	38.0	44.6	52.5	54.9
September	71.2	73.9	43.1	47.6	57.2	60.7
October	75.9	77.4	51.9	50.8	63.6	64.1
November	84.4	79.9	56.2	53.3	70.3	66.6
December	90.8	85.6	60.4	58.0	75.6	71.8
Year	77.0	75.8	50.2	53.5	63.6	64.7

X. Climatological data for Yudnapinna. Means of 17 years, 1939-1955.

Month	Rainfall inches	Relative Humidity per cent.	Air temperature, $^{\circ}$ F		
			Max.	Min.	Mean
January	0.71	45	92.4	63.6	78.0
February	1.11	50	89.1	63.2	76.1
March	0.59	50	85.8	58.9	72.3
April	0.57	60	75.5	51.8	63.6
May	0.89	68	68.3	46.2	57.3
June	1.02	79	62.5	41.5	52.0
July	0.67	76	61.5	39.1	50.2
August	0.63	68	65.9	40.8	53.3
September	0.43	54	72.7	45.1	58.9
October	0.81	48	77.4	50.7	64.0
November	0.73	44	83.7	55.9	69.8
December	0.78	41	89.6	60.8	75.2
Year	8.94	57	77.0	51.5	64.2

XI. Climatological data for Yudnapinna. Means of 17 years, 1939-1955, corrected to a standard month of 30.4 days.

Month	Rainfall inches	Saturation deficit inches of mercury
January	0.70	.495
February	1.19	.407
March	0.58	.366
April	0.58	.219
May	0.87	.134
June	1.03	.076
July	0.66	.078
August	0.62	.118
September	0.44	.225
October	0.79	.302
November	0.74	.391
December	0.76	.491
Year	8.96	.275

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Waite Agricultural Research Institute
University of Adelaide, 1954-1955

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Records of Field Experimental Work

I. PERMANENT ROTATION EXPERIMENT, 1926-1955. (C1)

Effect of different crop rotations on the yield of wheat.

Variety of crop and seed rate per acre: Sepoy wheat (1926-34), Seewari (1935-47), Seewari 48 (1948-55), 80-90 lb.; Early Burt oats, 60-70 lb.; Prior barley, 70-80 lb.; White Brunswick peas, 120-150 lb.; Wimmera rye-grass, 10-15 lb. (1926-45), and Wimmera rye-grass, 3 lb. + Fulghum oats, 40 lb. (1946-55) on the rotations wheat, pasture, fallow and wheat, oats, pasture, fallow; Wimmera rye-grass, 3 lb. + subterranean clover, 6 lb. on the rotations wheat, 2 years of pasture and wheat, 2 years of pasture, fallow; phalaris, 3 lb. + subterranean clover 6 lb. + lucerne, 1 lb. + Wimmera rye-grass, $\frac{1}{2}$ lb. on the rotations wheat, wheat, 4 years pasture, and the permanent pasture.

Basal dressing of superphosphate, 187 lb. per acre (1929-42), 94 lb. per acre (1944-55).

Design: Unreplicated, but each course of each rotation is represented each year.

Area of each plot = 1/7 acre (1926-37), 1/7-619 acre (1938-53). Total yields are based on air-dry weights of harvested crops and oven-dry weights of forage crops.

TABLE 1

MEAN YIELDS OF CROPS IN EACH ROTATION IN 1954 AND 1955, AND OVER THE DURATION OF THE EXPERIMENT. (FIGURES IN BRACKETS INDICATE THE NUMBER OF YEARS FOR WHICH REPRESENTATIVE YIELDS ARE AVAILABLE.)

Rotation	Grain, bushels per acre				Total produce, cwt. per acre*				
	Wheat	Barley	Oats	Peas	Wheat	Barley	Oats	Peas	Pasture
1954									
Wheat, fallow	19.4	—	—	—	31.4	—	—	—	—
Wheat, peas	18.5	—	—	18.3	21.3	—	—	16.4	—
Wheat, barley, peas	26.7	20.1	—	12.8	30.5	20.2	—	32.7	—
Wheat, oats, fallow	31.9	—	41.1	—	39.6	—	39.6	—	—
Wheat, pasture, fallow	35.3	—	—	—	43.5	—	—	—	34.8
Wheat, 2 years pasture: 1st year	37.3	—	—	—	44.8	—	—	—	22.0
Wheat, 2 years pasture: 2nd year	—	—	—	—	—	—	—	—	38.5
Wheat, 2 years pasture, fallow: 1st year	41.4	—	—	—	49.5	—	—	—	51.6
Wheat, 2 years pasture, fallow: 2nd year	—	—	—	—	—	—	—	—	86.5
Wheat, oats, pasture, fallow	52.6	—	39.1	—	61.8	—	34.3	—	27.1
Wheat, wheat, 4 years pasture: 1st year	20.3	—	—	—	34.8	—	—	—	41.0**
Wheat, wheat, 4 years pasture: 2nd year	12.5	—	—	—	19.0	—	—	—	100.6**
Wheat, wheat, 4 years pasture: 3rd year	—	—	—	—	—	—	—	—	103.8**
Wheat, wheat, 4 years pasture: 4th year	—	—	—	—	—	—	—	—	80.9**
Wheat continuously	16.7	—	—	—	22.8	—	—	—	—
Permanent pasture	—	—	—	—	—	—	—	—	110.0

* Air-dry weights of harvested crops, oven-dry weights of forage crops.

** Duration of the rotation not long enough for the results to be representative.

I. PERMANENT ROTATION EXPERIMENT, 1926-1955. (C1)—continued.

Rotation	Grain, bushels per acre				Total produce, cwt. per acre*				
	Wheat	Barley	Oats	Peas	Wheat	Barley	Oats	Peas	Pasture
1955									
Wheat, fallow	8.8	—	—	—	14.1	—	—	—	—
Wheat, peas	8.0	—	—	7.1	11.6	—	—	18.7	—
Wheat, barley, peas	12.8	16.7	—	10.9	17.4	18.1	—	21.5	—
Wheat, oats, fallow	5.9	—	24.7	—	17.3	—	24.3	—	—
Wheat, pasture, fallow	14.4	—	—	—	20.8	—	—	—	12.3
Wheat, 2 years pasture: 1st year	25.1	—	—	—	31.6	—	—	—	29.2
2nd year	—	—	—	—	—	—	—	—	58.0
Wheat, 2 years pasture, fallow: 1st year	21.1	—	—	—	28.8	—	—	—	51.2
2nd year	—	—	—	—	—	—	—	—	90.5
Wheat, oats, pasture, fallow	29.1	—	33.0	—	31.3	—	27.1	—	27.0
Wheat, wheat, 4 years pasture: 1st year	9.8	—	—	—	34.3	—	—	—	77.0**
2nd year	4.8	—	—	—	10.5	—	—	—	84.0**
3rd year	—	—	—	—	—	—	—	—	92.2**
4th year	—	—	—	—	—	—	—	—	88.4**
Wheat continuously	3.9	—	—	—	6.3	—	—	—	—
Permanent pasture	—	—	—	—	—	—	—	—	117.1
Mean yield to 1955									
Wheat, fallow	31.4(30)	—	—	—	46.2(30)	—	—	—	—
Wheat, peas	23.9(30)	—	—	18.3(28)	34.5(30)	—	—	27.8(30)	—
Wheat, barley, peas	24.0(4)	—	—	12.6(4)	24.9(4)	—	—	23.6(4)	—
Wheat, oats, fallow	32.4(29)	19.9(4)	—	—	50.0(29)	21.0(4)	35.3(29)	—	—
Wheat, pasture, fallow	37.3(29)	—	35.6(29)	—	52.3(29)	—	—	—	26.9(28)
Wheat, 2 years pasture: 1st year	33.8(4)	—	—	—	38.9(4)	—	—	—	23.6(4)
2nd year	—	—	—	—	—	—	—	—	46.8(4)
Wheat, 2 years pasture, fallow: 1st year	35.8(4)	—	—	—	45.5(4)	—	—	—	46.8(4)
2nd year	—	—	—	—	—	—	—	—	83.3(3)
Wheat, oats, pasture, fallow	43.6(28)	—	46.0(28)	—	62.2(28)	—	42.6(28)	—	29.4(28)
Wheat, wheat, 4 years pasture: 1st year	23.8(4)	—	—	—	38.3(4)	—	—	—	59.0(2)**
2nd year	12.2(3)	—	—	—	18.6(3)	—	—	—	92.3(2)**
3rd year	—	—	—	—	—	—	—	—	98.0(2)**
4th year	—	—	—	—	—	—	—	—	84.6(2)**
Wheat continuously	13.1(30)	—	—	—	24.6(30)	—	—	—	—
Permanent pasture	—	—	—	—	—	—	—	—	97.1(4)

* Air-dry weights of harvested crops, oven-dry weights of forage crops.

** Duration of the rotation not long enough for the results to be representative.

TABLE 2
YIELD AND BOTANICAL COMPOSITION OF PASTURE PLOTS, 1954 AND 1955. (OVEN-DRY WEIGHTS, CWT. PER ACRE.)

Rotation	Total	Sown Species					Volunteer Species		
		W.R.G.	Sub. Clover	Phalaris	Lucerne	Grazing Oats	Annual Legumes	Annual Grass	Miscellaneous
1954									
Wheat, pasture, fallow	34.8	Tr.	—	—	—	34.8	Tr.	Tr.	Tr.
Wheat, 2 years pasture: 1st year	22.0	4.4	Tr.	—	—	—	—	13.2	4.4
Wheat, 2 years pasture: 2nd year	38.5	6.9	14.6	Tr.	—	—	0.5	1.8	14.7
Wheat, 2 years pasture, fallow: 1st year	51.6	44.5	Tr.	Tr.	—	—	Tr.	7.1	—
Wheat, 2 years pasture, fallow: 2nd year	86.5	15.1	3.7	—	—	—	Tr.	67.7	Tr.
Wheat, oats, pasture, fallow	27.1	Tr.	—	Tr.	—	20.0	7.1	Tr.	—
Wheat, wheat, 4 years pasture: 1st year**	41.0	Tr.	0.3	2.1	Tr.	—	Tr.	38.6	Tr.
Wheat, wheat, 4 years pasture: 2nd year**	100.6	20.3	32.5	28.1	Tr.	—	Tr.	17.3	2.4
Wheat, wheat, 4 years pasture: 3rd year**	103.8	4.1	8.1	91.6	Tr.	—	Tr.	Tr.	Tr.
Wheat, wheat, 4 years pasture: 4th year**	80.9	Tr.	0.5	1.6	6.2	—	Tr.	71.5	1.1
Permanent pasture	110.0	Tr.	4.6	14.0	1.9	—	Tr.	89.5	Tr.
1955									
Wheat, pasture, fallow	12.3	0.4	—	—	—	11.7	—	Tr.	0.2
Wheat, 2 years pasture: 1st year	29.2	6.5	11.5	—	—	—	Tr.	0.6	10.6
Wheat, 2 years pasture: 2nd year	58.0	13.3	21.0	—	—	—	Tr.	4.7	19.0
Wheat, 2 years pasture, fallow: 1st year	51.2	3.8	17.3	—	—	—	8.7	12.6	8.8
Wheat, 2 years pasture, fallow: 2nd year	90.5	26.5	50.1	Tr.	—	5.8	Tr.	7.4	6.5
Wheat, oats, pasture, fallow	27.0	2.1	Tr.	—	—	—	4.9	14.2	Tr.
Wheat, wheat, 4 years pasture: 1st year**	77.0	4.5	7.2	—	—	—	25.5	39.1	0.7
Wheat, wheat, 4 years pasture: 2nd year**	84.0	0.6	21.0	50.5	Tr.	—	Tr.	9.3	2.6
Wheat, wheat, 4 years pasture: 3rd year**	92.2	7.5	7.2	18.2	—	—	1.7	55.9	1.7
Wheat, wheat, 4 years pasture: 4th year**	88.4	8.0	8.8	61.5	Tr.	—	Tr.	10.1	Tr.
Permanent pasture	117.1	Tr.	20.7	12.8	11.7	—	Tr.	64.1	7.8

** Duration of the rotation not long enough for the results to be representative.

II. INFLUENCE OF GRAZED AND HARVESTED FORAGE CROPS ON THE YIELD OF TEMPORARY PASTURE AND WHEAT IN FOUR-COURSE ROTATIONS, 1937-1955. (C53)

Present rotations:

1	2	3	4	5
Fallow Wheat Fallow Wheat	Fallow Wheat Oats Pasture†	Fallow Wheat Oats* Pasture†	Fallow Wheat Peas Pasture†	Fallow Wheat Peas Grazing Oats

* With sulphate of ammonia added.

† Wimmera rye-grass.

Variety of crop and seed rate per acre; Seewari 48 wheat, 80-90 lb.; Mulga oats, 60-70 lb.; White Brunswick peas, 120-150 lb.; Fulghum grazing oats, 60-70 lb.; Wimmera rye-grass, 10 lb.

Fertilizer: Basal superphosphate applied at 1 cwt. per acre. Sulphate of ammonia at 2 cwt. per acre applied to oats on rotation 3 at seeding.

Design: 60 main plots in 4 groups of 15 plots, each group representing one course of the rotations. The groups of 15 plots are divided into 3 randomized blocks in which each rotation is represented by a plot. The plots are subdivided into halves; one half the forage crop is grazed and on the other it is harvested.

Area of main plots = 1/6.94 acre.

Yields are based on air-dry weights of harvested crops, and oven-dry weights of forage crops.

TABLE 3
MEAN YIELDS OF CROPS FOR EACH ROTATION IN 1954 AND 1955.

Rotation	Management of 2nd course	Grain, bushels per acre			Total produce, cwt. per acre*			
		Wheat	Oats	Peas	Wheat	Oats	Peas	Pasture
1954								
Wheat, fallow	grazed	24.9	—	—	31.7	—	—	—
Wheat, oats, pasture, fallow	—	20.1	—	—	29.8	—	—	—
Wheat, oats + S/A, pasture, fallow	grazed	29.2	—	—	33.4	12.8	—	4.1
Wheat, peas, pasture, fallow	harvested	28.5	22.0	—	33.4	17.3	—	3.9
Wheat, peas, pasture, fallow	grazed	34.0	—	—	39.9	37.1	—	6.3
Wheat, peas, grazing oats, fallow	harvested	31.8	38.1	—	37.9	45.3	—	3.5
	grazed	43.9	—	—	54.8	—	50.3	10.4
	harvested	38.9	—	30.2	48.8	—	40.8	8.5
	grazed	43.8	—	—	54.3	24.1	45.0	—
	harvested	39.2	—	28.8	50.1	15.0	41.3	—
1955								
Wheat, fallow	grazed	7.5	—	—	15.4	—	—	—
Wheat, oats, pasture, fallow	—	8.5	—	—	20.3	—	—	—
Wheat, oats + S/A, pasture, fallow	grazed	11.5	—	—	19.5	12.1	—	13.6
Wheat, peas, pasture, fallow	harvested	11.2	13.6	—	20.7	11.7	—	6.7
Wheat, peas, pasture, fallow	grazed	15.6	—	—	21.8	37.6	—	28.9
Wheat, peas, grazing oats, fallow	harvested	16.2	34.2	—	21.7	34.0	—	9.0
	grazed	12.7	—	—	22.2	—	33.5	41.9
	harvested	10.7	—	12.0	21.4	—	20.6	36.4
	grazed	8.6	—	—	20.2	63.0	46.2	—
	harvested	10.8	—	12.7	21.7	62.0	22.3	—

* Air-dry weights of harvested crops, oven-dry weights of forage crops.

TABLE 4
MEAN YIELDS OF CROPS FOR THE DURATION OF THE EXPERIMENT.

Rotation	Management of 2nd course	Grain, bushels per acre			Total produce, cwt. per acre			
		Wheat	Oats	Peas	Wheat	Oats	Peas	Pasture
1949-55								
Wheat, fallow	grazed	23.8	—	—	31.8	—	—	—
Wheat, oats, pasture, fallow	—	22.0	—	—	30.5	—	—	—
Wheat, oats, pasture, fallow	grazed	29.5	—	—	36.5	9.2	—	7.0
Wheat, oats + S/A, pasture, fallow	harvested	27.3	9.5	—	34.3	7.8	—	4.9
Wheat, oats + S/A, pasture, fallow	grazed	33.8	—	—	41.3	33.9	—	10.7
Wheat, peas, pasture, fallow	harvested	29.7	37.7	—	36.1	35.9	—	5.2
Wheat, peas, pasture, fallow	grazed	39.7	—	—	50.9	—	38.2	25.6
Wheat, peas, grazing oats, fallow	harvested	33.9	—	19.9	43.5	42.6	25.8	18.9
	grazed	40.3	—	—	52.4	34.2	43.5	—
	harvested	36.4	—	24.4	46.8	—	30.6	—

TABLE 5
YIELD AND BOTANICAL COMPOSITION OF PASTURE PLOTS, 1954 AND 1955 (OVEN-DRY WEIGHTS, CWT. PER ACRE).

Rotation	Management of 2nd course	Total Yield	Spp. cut	
			W.R.G.	Miscellaneous
1954				
Wheat, oats, pasture, fallow	grazed	4.1	3.9	0.2
Wheat, oats + S/A, pasture, fallow	harvested	3.9	3.8	0.1
Wheat, oats + S/A, pasture, fallow	grazed	6.3	2.6	3.7
Wheat, peas, pasture, fallow	harvested	3.5	2.9	0.6
	grazed	10.4	10.0	0.4
	harvested	8.5	8.5	Tr.
1955				
Wheat, oats, pasture, fallow	grazed	13.6	7.4	6.2
Wheat, oats + S/A, pasture, fallow	harvested	6.7	4.5	2.2
Wheat, oats + S/A, pasture, fallow	grazed	28.9	7.3	21.6
Wheat, peas, pasture, fallow	harvested	9.0	6.8	2.2
	grazed	41.9	33.0	8.9
	harvested	36.4	30.5	5.9

III. INFLUENCE OF PASTURES AND FORAGE CROPS ON THE YIELD OF WHEAT GROWN IN ROTATIONS OF VARYING DURATION (C92). Combined field crop-pasture rotational experiment begun in 1947 with the object of comparing two-course and four-course rotations and an eight-course rotation, based on (1) Fallow, wheat; (2) Peas (grazed), wheat; (3) Pasture for two years, fallow, wheat; (4) Pasture for three years, wheat; (5) Pasture for six years, wheat, wheat.

The field has previously been subjected to a long period of wheat, bare fallow; and the investigations provide scope for examining the effects of the rotations on the nitrogen status and physical properties of the soil, as well as on forage and crop production.

Variety of crop and seed rate per acre; Secwari 48 wheat, 80-90 lb.; White Brunswick peas, 120-150 lb. Pasture mixture of *Bacchus Marsh* subterranean clover, phalaris, *Wimmera* rye-grass, lucerne. Basal superphosphate 112 lb. per acre per annum with each season of crop and of pasture.

All five of the rotations were commenced in each of the three seasons 1947, 1948, 1949. Those begun in 1949 were originally established in 1946 but not proceeded with until 1949.

Total of 30 plots, each 2.00 x 0.40 chains (1/12.5 acre), made up of rotations (5) x seasons (3) x replications (2).

TABLE 6

MEAN YIELDS OF CROPS FOR EACH ROTATION, 1954 AND 1955.

Rotation	Grain, bushels per acre		Total produce, cwt. per acre								
	Wheat 1st year	2nd year	Peas	Pasture 1st year	2nd year	3rd year	4th year	5th year	6th year	Wheat	
										1st year	2nd year
1954											
Wheat, fallow	28.9	—	—	—	—	—	—	—	—	47.8	—
Wheat, peas (grazed)	26.4	—	34.0	—	—	—	—	—	—	34.8	—
Wheat, 2 years pasture, fallow	50.1	—	—	—	71.0	—	—	—	—	73.5	—
Wheat, 3 years pasture	35.9	—	—	—	70.2	86.0	—	—	—	51.2	—
Wheat, wheat, 6 years pasture	27.4	22.1	—	—	—	—	—	—	89.2	*	30.4
1955											
Wheat, fallow	11.3	—	—	—	—	—	—	—	—	27.2	—
Wheat, peas (grazed)	25.2	—	38.2	—	—	—	—	—	—	34.0	—
Wheat, 2 years pasture, fallow	26.5	—	—	—	—	—	—	—	—	48.4	—
Wheat, 3 years pasture	21.4	—	—	—	—	93.6	—	—	—	37.6	—
Wheat, wheat, 6 years pasture	—	4.5	—	—	—	—	—	—	—	—	13.6

* Straw not harvested.

TABLE 7
YIELD AND BOTANICAL COMPOSITION OF PASTURE PLOTS, 1954 AND 1955 (OVEN-DRY WEIGHTS, CWT. PER ACRE).

	Crop	Total	W.R.G.	Phal.	Sub.	Lucerne	Annual Grass	Annual Legumes	Misc.
1954 Wheat, pasture, fallow Wheat, pasture, pasture pasture Wheat, wheat, 6 years pasture	2nd year pasture	71.0	Tr.	3.1	32.6	Tr.	35.3	Tr.	Tr.
	2nd year pasture	70.2	Tr.	5.6	29.9	Tr.	25.0	0.5	9.2
	3rd year pasture	86.0	24.1	7.0	24.7	Tr.	13.2	Tr.	17.0
	6th year pasture	89.2	Tr.	14.9	3.2	0.4	70.7	Tr.	Tr.
1955 Wheat, pasture, pasture, pasture	3rd year pasture	93.6	3.2	15.5	35.4	2.4	34.4	—	2.7

TABLE 10
COMPARATIVE CROP TRIALS, 1954-1955.

Crop	Variety	1954				1955			
		Flowering date	Yield lb/acre	Oil			Yield lb/acre	Oil	
				% Oil	lb/acre	Iodine Number		% Oil	lb/acre
Wheat:	Seewari	12.10	1609 ± 116	—	—	—	2399 ± 158	—	—
Linseed:	Walsh	29.9	213 ± 28	40.5	81	188	778 ± 38	43.5	319
	Punjab 5	25.9	856 ± 28	44.0	355	190	545 ± 98	44.0	226
	Uruguay	—	—	—	—	—	1165 ± 87	34.5	379
Safflower:	23	25.11	1283 ± 45	34.0	412	147	1168 ± 87	30.0	332
	(48.89)	21.11	1199 ± 65	33.0	373	147	101 ± 13	31.0	148
	(47.53)	21.11	864 ± 90	37.0	302	144	1382 ± 87	35.0	456
	4	—	—	—	—	—	1331 ± 200	—	—
Rape:	Black Argentine	—	—	—	—	—	—	—	—
		Plot Size: 1/42 acre Sown: June 18 Poor emergence on several plots of safflower (47.53).				Plot Size: 1/47 acre Sown: July 6 *Very wet conditions following sowing resulted in very poor emergence of safflower (47.53) and it was resown on August 17.			
		Pests and Diseases: Linseed affected by Pasm disease and rust; Walsh bolls suffered bird damage.				Pests and Diseases: Linseed dusted with D.D.T. to control Heliothus on November 3. Punjab 5 affected by rust; Uruguay bolls suffered bird damage.			
		Harvest Dates: Wheat—December 2 Linseed—December 2 Safflower—January 10				Rape sprayed to control aphids on November 3. Harvest Dates: Wheat—December 16 Linseed—December 30 Safflower—January 24 Rape—November 28			

Commonwealth Scientific and Industrial Research Organization

DIVISION OF SOILS

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(as at 31st December, 1955):*

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Sectional Draughtsman: P. D. Hooper.

Note: There are five Regional Centres—Brisbane, Hobart, Perth, Canberra and Deniliquin—permanently staffed with research officers of the Soil Survey, Soil Chemistry and Soil Physics Sections.

Soil Microbiology Section:

Principal Research Officer: R. J. Swaby, M.Sc., M.Ag.Sc., Ph.D.

Research Officer: J. R. Harris, M.Sc., J. N. Ladd, M.Sc.

Technical Officer: Joan I. Sperber.

Technical Assistants: Grace Banos, Anne C. Tait.

Laboratory Workshop:

Technical Officer: A. W. Palm.

Laboratory Craftsman: K. J. Barrow.

Scientific Instrument Maker: A. D. Adey.

C.S.I.R.O. Officers who have left for other appointments since 1st January, 1954:

D. S. McIntyre, Canberra; R. S. Beckwith, Brisbane; A. D. Haldane, Canberra; M. J. Mulcahy, Perth, W.A., Janet R. Wylie, F. W. Pedler, M. C. Coulls, M. J. Spooner, Bayes Lloyd, Margaret Altman, P. Oenone McKenna.

Commonwealth Scientific and Industrial Research Organization

Division of Soils

1. INTRODUCTION.

The Division of Soils of the Commonwealth Scientific and Industrial Research Organization has its headquarters at the Waite Agricultural Research Institute, Adelaide, and a close relationship between the associated research bodies has been maintained. The central organization of the Division has remained without major developments, but more active regional laboratories have functioned in other centres in combination with the survey work. A new laboratory has been occupied at Canberra and another at Perth.

Pedological research has come more strongly into the soil survey programme. Principles of soil occurrence, soil genesis and relationship with geomorphic formations have become of greater importance. Geochemical studies on soil-parent material relations have begun. Clay mineralogy research has advanced and with new laboratories is developing its programme. A Soil Mechanics Section has been formed from within the Soil Physics Section and is steadily growing in vigor and scope of work.

Five officers have been overseas on study leave for periods of two to twelve months. One attended the 5th International Soil Science Congress in the Belgian Congo. Two officers have been on studentships through 1954-5.

2. SOIL SURVEY AND PEDOLOGY.

OPERATIONS IN SOUTH AUSTRALIA.

All the fieldwork and in large part the land use reports for the Barossa District survey have been completed and await publication in four parts. The reports, following that of the Nuriootpa area previously published, together represent a very full study of the soils of the district which is the most important single wine-producing area in Australia. They cover the following units: (I) The Nuriootpa area (see Soils and Land Use Series No. 13, 1954); (II) the Angaston-Springton and Tanunda Creek-Trial Hill areas; (III) the Greenock-Gomersal area; (IV) the Tanunda-Williamstown area. The soil map for the whole Barossa District showing the distribution of the major soil groups has been compiled and virtually completes the work except for a later pedological discussion. Data for a memorandum on soil and climatic factors in relation to wine type and quality arose from the Barossa studies and this has proved of value to those responsible for the future programme of the Wine Research Institute.

The survey of the area around Lakes Alexandrina and Albert, South Australia, progressed favourably during the period. This region has available large supplies of fresh water which might be used for irrigation. Studies have been made of soil salinity and irrigability and the classification and correlation of the soil groups have been carried out. The survey will provide much needed basic data

concerning the soils and their potential under rainfall conditions as well as the desirability of their more intensive development under irrigation.

The investigations at Yudnapinna Station in the north-western pastoral country, commenced in 1954, were concluded in 1955. A reconnaissance soil survey of the entire property of about 1,300 square miles and five separate detailed surveys totalling about 10,000 acres were made. A number of infiltration trials were conducted on typical soils. Rain gauges were installed on several dam catchments and water intakes were measured at these dams after rains in order to obtain run-off data. The report of the Yudnapinna investigations now completed includes an analysis of the available climatic data, a brief description of the physiography and geology, an account of the vegetation, descriptions, and map showing distribution of soil types and soil associations, and a presentation and discussion of the data relating to soil water, infiltration and run-off.

A soil map and report for the Tatiara district in the upper south-east, surveyed earlier, have now been compiled for publication. In connexion with investigations by the Soil Physics Section (see p. 13) a reconnaissance inspection of an area south-east of Meningie was made in the first place to determine the local soil features, the problems involved in the soil moisture investigations; and to select experimental sites. In County Grey, a recent reconnaissance soil survey of 2,044 square miles completed in periods totalling 10 weeks' fieldwork, represents the latest approach to such broad mapping using data from detailed surveys as a working basis. The report from this survey will furnish an up-to-date account of the soils and land use in a most productive part of South Australia. It is expected that a more accurate soil map of south-eastern South Australia will be completed within two years following this principle as a large amount of information on unit areas is available.

OTHER PARTS OF AUSTRALIA.

Surveys have continued in all States and the North Australia Survey party has operated in Northern Queensland. Mapping from detailed to broad reconnaissance has been carried on and a move made into investigation of arid and semi-arid soils in Queensland and central Australia.

3. SOIL CHEMISTRY.

PEDOLOGICAL STUDIES.

The study of the inter-relationships of terra rossa and rendzina soils of South Australia has been completed. As was mentioned in the last report, their colour could be related to the ratio of free ferric oxide to organic matter. All other chemical characteristics showed an overlapping range of values for both groups of soils. It was therefore suggested, because of this similarity in chemical characteristics and the steady progression in colour from black to red on one hand and black to grey on the other, that the soils of these two groups could be considered as part of one sequence of soils. In any classification this sequence could be given individual status and subdivided into red, brown, black and grey members, analogous to the subdivision of the podzolic soils. It has therefore been proposed that all profiles having a shallow to moderately shallow solum with no marked textural differentiation throughout and overlying calcareous material be designated *terra-cal* with a qualifying term to describe particular profiles, e.g. red *terra-cal*, brown *terra-cal*, black *terra-cal*. Profile

samples representing occurrences of this group of soils in other parts of the world have now been collected and are being examined to test the applicability of these conclusions generally.

The next group of soils to be examined are the solonchak, solonetz, solodized solonetz and solod, occurring throughout the Upper South-East of South Australia and the Western District of Victoria and a number of typical profiles have already been collected.

MICRONUTRIENT METALS IN SOILS AND THEIR UPTAKE BY PLANTS.

The use of disodium calcium versenate as an extractant of divalent manganese in soils has been described in a recent publication and in a second paper evidence has been presented to indicate that organic matter of some soils can complex metals of the first transition series. It is thought that complexes of copper with organic matter may be the most important product of weathering of this metal in soils. The formation of metal complexes in organic soils does not necessarily mean that the metals so combined are unavailable to plants. In fact, experimental evidence is against this in many cases. Possible steps in the uptake of micro-nutrient metals from organic soils have been discussed.

A pot experiment has been carried out for several years to compare the relative values of some precipitated oxides of manganese and manganous sulphate as sources of manganese for oats growing on a fen soil from Rendelsham, S.A. Experiments were carried out at the natural pH of the soil (pH 6.2) and with the same soil limed to above pH 8. The three oxides had the approximate compositions Mn_3O_4 , Mn_2O_3 and MnO_2 and the structures of hausmannite, manganite and manganous manganite respectively. All were quite effective sources of manganese for oats growing in this soil at its natural pH, and all were superior to the equivalent amount of $MnCO_3$. At pH 8, however, only manganous manganite retained its high availability. The residual value of this oxide has been greater and notably more prolonged when added to the limed soil than when added to the soil at pH 6.2. This is considered to indicate a fixation mechanism involving reduction and re-oxidation of manganese rather than simple ageing of the oxide crystals. Such a mechanism would also explain the lower immediate value and residual value of manganous sulphate compared to the equivalent amount of some precipitated oxides.

A study has been commenced of the interactions of some micro-nutrient metals, notably the effects of copper and zinc, in lowering the uptake of manganese by plants. Depression of manganese uptake has been noted following additions of copper, even when the plants without copper were suffering from a deficiency of manganese.

GEOCHEMISTRY OF SOILS.

Geochemical work has begun in attempting to relate certain soils of the South-East of South Australia to the underlying volcanic materials from which they have been formed. At present the older volcanics of the Mt. Burr Forest are being studied. The distribution of 18 elements in the parent materials, soil profiles and the clays separated from different horizons of these profiles is being examined by spectrochemical and chemical methods to determine their redistribution under the influence of the different processes of soil formation. The use of total zirconium (determined spectrochemically) as an index of weathering has enabled some broad trends to be discerned but full interpretation is hampered by lack of homogeneity in some profiles and possible movement of

zirconium down the profile. The mode of transfer of essential nutrients from the weathering tuff to the over-lying sands is being studied. This is of importance in the nutrition of the pine forests.

RAINWATER STUDIES.

Rainwater samples have been collected at regular intervals, in conjunction with the S.A. Department of Woods and Forests and the Soil Conservation Authority of Victoria. It was found desirable to restrict the samples to monthly rather than longer periods to avoid undue changes in composition with storage or contamination. The pattern of variation in composition of the rainwater with distance from the coast is becoming clear. Two lagoons in the Barossa district are being studied in order to obtain information on the accession of soluble materials. Samples of water have been collected monthly and at the same time the levels of the lagoons have been recorded.

CLIMATOLOGY.

An assessment of the potential evapotranspiration is essential in order to calculate the average amount of rainfall available for soil leaching. A method has been developed which will enable the approximate calculation of potential evapotranspiration from normal monthly mean and minimum temperatures. This makes it possible to extend the calculations of Prescott to meteorological stations which do not keep relative humidity records, and to check values derived by other methods.

Calculations of the average amount of rainfall available for soil leaching, based on the balance between rainfall and potential evapotranspiration, have shown satisfactory agreement with the major soil boundaries in South Australia. This technique should prove useful in determining the importance of the present regional climate in the distribution of soil groups. A general method for mapping the calculated values has been devised and some tentative maps of parts of southern Australia have been compiled for comparison with known soil distributions.

PHYSICAL CHEMISTRY.

Soil pH Mechanisms: The work on ion exchange-pH relationships has been continued both in Adelaide and also at Wageningen, Holland, during an overseas visit by the officer concerned, to elucidate further the processes involved in determining the pH of a soil. If pH_0 designates the pH of a soil with a very small amount of salt present the different cation-dominant soils studied showed that when salt was added the quantity $pNa-pH$ is a constant if pH_0 is nearly 7, in accord with the Donnan equilibrium. However, if pH_0 is less than 7, then $pNa-pH^x$ is approximately a constant. The quantity X is greater than unity and increases with decreasing pH_0 . These results are explained by an increase in hydroxyl ion production as the pH decreases. This comes from reactions upon salt addition which involve the aluminium ion both in solution and on the soil. These reactions then compete with reactions resulting in the formation of hydrogen ions (most simply the exchange of hydrogen ions on the soil with added cations).

Dialysis of sodium saturated soils against hydrogen saturated ion exchange resin has been used to secure a range of acid soils without the production of an accompanying salt and additional experimental data have been obtained from dialysis studies on these. Only very small amounts of aluminium ions (circa

10^{-5}M) occurred in the dialysates of the prepared soil suspensions and this concentration was only attained by aluminium ions at pH values less than about 3.3 and by aluminate ions at pH values greater than 10.8. These soil suspensions contained very low amounts of salt; if the amounts of salt were increased higher concentrations of aluminium ions would be found.

In acid dialysates the amount of silicon released into solution was not dependent on the quantity of sodium in solution nor the amount of exchangeable sodium on the soil. Neither was there any relationship between the amounts of sodium in the dialysates and their pH. In acid dialysates, however, the pH and the silicon in solution were dependent on one another in a way which varied slightly with the concentrations of the soil suspensions. Whilst many factors may contribute to this effect, the solubility relationships of a compound such as $\text{Al}_2\text{O}_3 (\text{SiO}_2)_{16}$ provide the best explanation at present. In alkaline dialysates the silicon in solution, after a sudden drop at pH 7 to about one-sixth of its value in the acid dialysates, remains at a constant value of about $3 \times 10^{-5}\text{M}$ up to about pH 10. After this, the quantity of silicon in solution increases in a similar way to that predicted by calculations from the first and second dissociation constants of silicic acid. The minimum of silicon in solution in the alkaline pH range arises either from the aluminium ion equilibria or as a consequence of the polymerization of silicic acid. Above pH 7 definite relationships exist between the percentage sodium saturation of the soil and the pH and also the pNa in the dialysate; below pH 7 these relationships are indefinite.

Consequently, it appears that whilst the pH of the acid dialysates depends upon a silicic acid compound, possibly with aluminium, in alkaline dialysates the pH is directly related to the percentage saturation of the soil. These results show that a change of pH from acid to alkaline could bring about deposition of silica from solution and this may be important in the formation of siliceous cappings which occur in the B horizon of solodized solonetz and solodic soils. These results also show that the simple considerations sometimes applied to the action of salt and water on the hydrogen ion status of soils are in reality not justified.

An Anomalous Suspension Effect: While measuring the suspension effect in dialysing soil systems it was found that for soils treated with monovalent cations the observed potentials were of the correct sign for soils. However, soils treated with divalent ions gave observed potentials of an opposite sign to that expected. Determinations were made of the rates of change of potential between the two calomel electrodes in concentrated and dilute salt solutions on either side of thin horizontal beds of sedimented ion exchange resins which were saturated with various monovalent or divalent cations. These measurements showed that when a potassium chloride front diffused into a bed of, say, calcium resin, a calcium chloride front arose ahead of the potassium chloride front. The liquid junction potential that was set up between the solution phase of the resin and this calcium chloride front was of such a sign and magnitude to give rise to the anomalous suspension effect for calcium soils and clays. By applying corrections based on the Henderson equation, complete agreement was obtained for the suspension effect measurements made upon soil suspensions containing either monovalent or divalent ions. This represents the first experimental proof of the exact nature of this anomaly.

Exchangeable Hydrogen: The techniques used in this laboratory have employed dilute calcium hydroxide-nitrophenol buffer solutions, which means that

values are not necessarily comparable with exchange capacities and exchangeable cations determined on normal ammonium salt solutions. A number of alternative buffers using p-nitrophenol or mannitol-boric acid with various alkalis, as well as some unbuffered solutions such as ammonium chloride plus ammonia have been tried as alternatives. For each soil sample a wide range of values for exchangeable hydrogen was found. Apart from specific differences between cations of the same valence, the values interpolated to the same equilibrium pH increased with valence of the cation and concentration of the solution. It is evident from these results that the choice of a technique for exchangeable hydrogen, and hence exchange capacity, is arbitrary. It may well be decided by analytical convenience or by suitability for inclusion in a more comprehensive system of exchangeable ion determinations. From this point of view unbuffered solutions are very attractive, since titration of the residual alkali is simple and salts which are suitable for the determination of both exchange capacity and exchangeable metal cations may be used.

Exchangeable Ions: During the development of techniques for the determination of exchangeable ions on small quantities of soil material, it became apparent that existing techniques were not suitable for adaptation to micro-analysis, partly because of manipulative difficulties, but more particularly because they do not provide a consistent set of values. A safe technique must minimize solution of non-exchangeable ions and the formation of insoluble compounds. Moreover, cations commonly found in soils cannot be used if a single equilibrating solution is desired. These considerations restrict the choice of a replacing salt solution to that of an ammonium-type cation. These cations are also suitable for exchangeable hydrogen determination with unbuffered solutions.

A detailed study of the equilibria involved is now in progress and suitable techniques are being developed. It is impossible to determine cation exchange capacity by this or any other method, unless anion exchange is zero, unless the water adsorbed from the solution can be estimated or the ammonium salt held by the soil at the last treatment can be removed. If these limitations can be overcome a method will be available for the determination of exchangeable hydrogen, exchangeable metal ions, net negative charge and cation and anion exchange capacities. These five values are concordant and any four should determine the fifth. The concordance of the results is the test for safety when the method is applied to soil materials.

SPECTROCHEMICAL INVESTIGATIONS.

In a study of the red brown earths from the Barossa Valley a correlation was found between the concentrations of gallium, vanadium and molybdenum in the A₁ horizons of all profiles and the clay contents of those horizons. An investigation of the distribution of six elements in several profiles revealed the following order of decreasing mobility—cobalt, copper, gallium, vanadium, molybdenum, manganese. In any one profile the concentration of each of these elements except manganese was correlated with the clay content of the horizon.

Because of recent interest in lead in wines, resulting from legislation in Britain specifying tolerances, several soil profiles from within and near vineyards have been examined for lead. The concentrations of lead were too low for precise quantitative analysis, but qualitative analysis showed that all samples contained lead in amounts between 1 and 25 parts per million.

Spectrochemical techniques have continued to be developed and they have now reached a stage where considerable confidence can be placed in the validity of the results. In an investigation of sampling errors, the error associated with the taking of a single sample in the field was of the order of 10 per cent. The spectrographic error of a triplicated analysis only increased the total error to 12 per cent.

The method of "successive additions" in spectrographic analysis was further tested, particularly in regard to copper and manganese under a wide range of conditions. It was found that for given composition and conditions of excitation the relationship was such that the method could be used for both elements. It was also found that the influence of varying basic composition was much more complicated than is frequently assumed.

Methods involving internal standards, widely used in spectrochemical determinations of metals and alloys, have often been incorporated into methods for soils and other refractory mineral powders. It would appear, however, that no one has ever investigated any gain in precision when so applied, in spite of going to considerable trouble to incorporate such elements in the samples. In such an investigation for soils and plant ash it was found that no real gain in precision was obtained except in special cases. Another common assumption that a practice used in metallurgical analysis, the precise control of arc current, would give equally precise analytical results when applied to soils was also tested. The results showed clearly that continuous control gave no increase in precision for elements of low and medium volatilities, but it did give a significant increase for involatile elements. Simple manual control was sufficient; expensive automatic devices for control of arcing current were not warranted.

The validity of the application of statistical techniques to spectrochemical analyses has been examined and two common assumptions have been shown to be essentially correct. The spectrographic error has been shown to be reproducible, within a narrow range, over a considerable period of time and in the hands of different analysts. Secondly, it has also been shown that the frequency distribution of the error gave no measurable departure from normality in a test on 408 triplicate soil samples. A small departure only was detected in 552 measurements in sextuplicate on plant ash; the departure here was small and would have little effect on common statistical tests.

A mechanical calculator designed and constructed in this Division has greatly simplified the correction of line intensities for background intensity and this has greatly reduced the time needed for calculations.

MISCELLANEOUS.

A co-operative study, at headquarters and in the Regional Laboratories, of the ethylene diamine tetra acetate titration for calcium and calcium plus magnesium disclosed that the accuracy generally obtainable by all observers in the titration of calcium plus magnesium was highly satisfactory using eriochrome black T as indicator. The titration could be carried out satisfactorily in either aqueous or ammonium chloride extracts of soils. The results obtained in the titration of calcium only, using murexide as indicator, were somewhat more variable and showed a tendency towards low results in the presence of large amounts of magnesium, unless the alkalinity was very closely controlled. This was thought to be due to the co-precipitation of calcium with the precipitate of magnesium hydroxide. A modified technique has now been evolved and

this enables the accurate titration of calcium without the need for such critical control of the alkalinity.

Phthalein purple (phthalein-complexone) has been found to be a sensitive indicator for alkaline earth and magnesium ions. When mixed with naphthol green B, in ammonium chloride powder, it may be used in the same way as eriochrome black T, over which it possesses a number of advantages. It does not give colours with traces of the heavy metals and it gives sharp end points even in ammonium chloride solutions. The clarity of the end point makes it especially suitable in the micro-titration of exchangeable calcium and magnesium.

The ethylene diamine tetra acetate method has also been found satisfactory for the determination of small amounts of sulphates in soils, provided a small but sufficient excess of barium chloride is used to ensure complete precipitation.

The dithionite method for the determination of free iron oxide in soils has been examined as an alternative to reduction by zinc powder in an oxalate buffer. The two methods gave very similar results for most soils and clay separates. Sodium dithionite ($\text{Na}_2\text{S}_2\text{O}_4$), however, removed less iron from the clay mineral nontronite and also from the iron mineral ilmenite. The method also has some advantages when it is desired to recover the soil residues for further examination.

The application of flame photometry to the determination of sodium and potassium in soluble and exchangeable forms in soil has been further studied. The error due to calcium, in the determination of sodium, can be greatly reduced by prior conversion to sulphates. The use of an interference filter in place of the usual gelatine filter further reduced this source of error to an almost negligible amount.

The grinding of plant samples without contamination by iron from steel mills has always been difficult. A Christy and Norris Mill has been modified to make it suitable for grinding such samples. Surfaces with which plant materials are in contact have been protected either with hard chromium plating or with a layer of Araldite casting resin. Tests with this mill have shown that grinding is effected without contamination and iron and copper may now be determined on the same ground sample.

4. SOIL PHYSICS.

FIELD MEASUREMENT OF WATER CONTENT OF THE SOIL.

A method using neutron scattering as a function of soil water content has been used to follow seasonal soil moisture changes for almost two years, with good success. The technique still needs to be improved to enable measurements to be made near the surface of the soil. It is probable that this can be done and work is being directed to that end. A paper has been published, which shows that calibration of the instrument may be helped considerably by a resort to neutron diffusion theory. This calibration refers to the probe (and neutron source) being enclosed in an effectively infinite medium. For measurements near the surface of the soil this calibration is not valid, and calibration to suit the geometry of a semi-infinite medium will be attempted.

The Division's equipment for measuring water content by neutron scattering would not be conveniently mobile for many operations. Arrangements have been made with the Department of Mines, S.A., for the redesign and building of equipment for field use, which is more suitable for routine measurements of soil water content. This apparatus is being tested for such features as accuracy and stability. It promises to be very satisfactory.

MEASUREMENT OF EVAPORATIVE LOSSES FROM SOIL.

The neutron scattering technique is being put to use in an investigation in undeveloped land 30 miles from Meningie, S.A. The question has been raised whether the evaporation from the present natural heath is different from that to be expected when the land is cleared and sown to pasture. The supplies of stock water come from underground, shallow aquifers, apparently fed by drainage from the small excess of rainfall over evaporation in the winter months, and it is important that these supplies should be recharged seasonally. Therefore, measurements are being made on the soil water storage at two sites in and near the area, which have been selected as representing the two conditions of land cover, viz. natural heath and sown pasture. The Division is co-operating with the Department of Mines, S.A., in this work. The depth and quality of water in holes at the experimental site are being followed by the Department.

The measurement of evaporation given by the neutron moisture meter is derived from changes in soil water storage and rainfall records. Evaporation may also be obtained from meteorological data, if a theory of the nature of the water vapour transfer to the atmosphere is used quantitatively. A comparison of the values for evaporation given by the two methods is being made. The limit on evaporation rate imposed by lack of water when the soil is drying is also being studied.

Other measurements of losses and gains of water in soil are being conducted in relation to moisture changes under houses. This is a long-term study which has been reported upon previously.

PERMEABILITY OF SOIL.

Measurements of permeability in a column of soil at water contents ranging from approximately field capacity to wilting percentage have been obtained by a technique of supplying water under tension to one end of the soil column and allowing evaporation to take place at the other end.

This technique has now been refined to enable the evaporation conditions to be varied more readily, and to allow the evaporation rate to be measured, so that equality of evaporation rate with rate of intake of water, together with constant readings of water tension within the column, determines when steady state flow is taking place.

The same apparatus will be used to determine, on a laboratory scale, the soil structure factors which govern the loss of water from soil under fallow conditions and ways in which this loss may be reduced.

SWELLING.

Relations between volume of soil, water content, and tension of the water in swelling and shrinking soils have been determined under laboratory conditions. Hysteresis occurred in each wetting and drying cycle in the relation between the water content and tension of the soil water. This was considered to be due to the internal rearrangement of particles accompanying change in volume.

A comparison is being made between the swelling of the calcium saturated clay mineral montmorillonite and the swelling of soil clays. The film thickness for a soil clay (illite), obtained by dividing the volume swelling by the surface area as determined by nitrogen adsorption, is approximately 20 Å. This compares with 5 Å in the fully swollen calcium montmorillonite. The reason for this difference is being investigated.

SURFACE AREA OF SOILS.

The negative adsorption of chloride ions by sodium and potassium clays has been used to measure the surface area of these materials. The surface areas obtained by these methods are in good agreement with those obtained from low temperature nitrogen isotherms. For montmorillonites the potassium ion is used since the internal separation of the elementary silicate sheets making up a crystal never exceeds 5.4 Å. The rate of change in the volumes, from which chloride ions are excluded, with concentration is governed by the external surface. Hence the method can be used to obtain the external surface.

This method has been used to study the effect of pretreatment on the external surface of bentonite. With moderate shaking it has been possible to vary the measured external surface from an initial 20 m²/g to 200 m²/g. The total surface (internal and external) is known from the structure of the clay mineral to be 760 m²/g.

The water vapour adsorption isotherms of a number of clay minerals are being examined in relation to surface area and exchangeable cations.

PORE SIZE DISTRIBUTION OF NATURAL SOIL AGGREGATES.

The pore size distribution of natural soil aggregates has been studied by using non-polar liquids which do not cause swelling. The liquids used were 1, 1, 2, 2, tetra chloro-ethane and benzene. The aggregates were dried over P₂O₅ and then saturated with the above liquids, which were then withdrawn by suction plate, pressure membrane apparatus and vapour sorption techniques to known energy levels from which the pore size could be obtained. Pore sizes were calculated down to 15 Å. All the clay soils despite their markedly different swelling characteristics exhibited a pore volume maximum at a pore size of 30,000 Å (equivalent to pF 2.5 for water). This work is being continued to include pores smaller than 15 Å because it is considered that important differences in soil behaviour might be associated with these fine pores. The use of both water and non-polar liquids represents a new approach in studying soil swelling.

STABILITY OF SOIL AGGREGATES.

Work concerning the effect of initial water content and energy condition in the soil water on the stability of soil aggregates has been undertaken. The important factor in aggregate breakdown is the rate of wetting. Aggregates which are unstable when wetted suddenly can be made stable by wetting slowly before immersion in water.

Aggregates show signs of failure when wet under tension at a sufficiently rapid rate. The water content for a number of unstable soils when wet at 2 and 10 centimeters of water tension was increased by increasing the rate of wetting. The increased rate of wetting caused planes of failure which accommodated the additional water. The breakdown of aggregates is small if they are previously wet slowly to a tension of 100 cm. or less before immersion in water. Dry clay soil aggregates were not stable when wet under vacuum because the high rate of wetting caused differential swelling.

Aggregates from virgin loam soil were completely stable when immersed in water, whereas those from the same cultivated soil broke down completely. In this loam soil there appeared to be a relation between mechanical strength of the dry aggregate and water stability.

MECHANISM OF THE ACTION OF SOIL STABILIZERS.

Viscosity measurements have shown that the "Kriliium" molecule will not pass through 10 micron diameter pores in a sintered glass filter. Since soil pores would also be negatively charged it can be inferred that "Kriliium" does not enter these pores. It is thought that "Kriliium" acts in the same way as organic matter and is precipitated by calcium in the large soil pores.

Soil aggregates from a continuously cultivated red brown earth soil have been treated with "Kriliium" and have been found to have properties very similar to the virgin soil aggregates.

RELATION OF FREE IRON CONTENT TO STRUCTURE.

In the course of an examination of the physical properties of terra rossa and rendzina soils a close relation was noted between the free iron content and the volume occupied by large pores (macroporosity).

Macroporosity was found by measuring total porosity at 100 cm. tension using a method developed in this laboratory and water content at this tension. Water stability was measured by wet sieving. There is a high correlation between macroporosity and free iron associated with the clay in these soils, even though the organic matter contents differ considerably. It would appear, however, that high organic matter (at any free iron level) increases macroporosity. This factor tends to separate these soils into two groups on macroporosity values, the macroporosity of the rendzinas (higher organic matter) being greater than that of terra rossas at the same iron level.

SURFACE SEALING OF SOIL BY RAIN.

The mechanism of formation of thin seals on soils under heavy rain has been investigated using a red brown earth. Some field measurements have been made, but most of the work has been carried out in the laboratory under simulated rainfall. A technique has been developed for measuring permeability of these seals which are of the order of one-tenth of a millimetre thick. Using this technique and measuring permeability under various conditions, it has been found that seals on an unstable cultivated soil have much lower permeability than those on a virgin soil newly cultivated. The seal formed on the poorly structured soil after heavy rain has a permeability whose value is of the order of one two-thousandth of that of the underlying soil. Investigation tends to show that washing in of fines does not ordinarily proceed further than the top tenth inch and that compaction of this surface by impact and the orientation of clay and silt at the surface are the dominating factors in lowering permeability.

SOIL STRUCTURE, CRUSTING AND GERMINATION.

Investigations into the effect of structure decline and surface crusting under heavy rains show that the poor germination of wheat under these conditions is most probably a result of lack of air. The effect was much worse in a fallow-wheat rotation than in a fallow-wheat-peas-pasture rotation and crusting on the former was considerably greater than on the latter. Crusts formed had almost zero pore space available for air at field capacity and under the wet conditions that prevailed at the time it seems likely that diffusion of air to seed and root depth was prevented.

GENERAL.

A number of measurements of soil physical properties have been undertaken and advice given on equipment for other laboratories. Enquiries have been handled concerning soil drainage, water-proofing of dams, run-off of water from soil, and soil temperature and moisture distribution in relation to electrical power lines.

A number of experiments are being carried out on the Waite Institute fields and the co-operation of the University in this is appreciated.

5. SOIL MICROBIOLOGY.

PHOSPHATES AND SOIL MICROORGANISMS.

This research has been divided into two projects, one dealing with the microbial assay of available phosphates, the other with the mechanisms of solubilising phosphates.

(1) AVAILABILITY OF PHOSPHATIC MATERIALS.

This work was undertaken to find whether soil microorganisms have similar difficulties in obtaining fixed phosphates as do plants growing in certain soils. Two dissimilar fungi were used for bioassaying available phosphates, viz. *Aspergillus niger*, which produces organic acids, and *Curvularia geniculata*, which maintains neutral conditions. In addition, assaying was carried out using the soil's own mixed microflora by comparing the respiration in the presence of phosphates differing in availability. Assays have been completed for 61 mineral phosphates, very few of which have been detected in soil as yet. Of those which might occur in soil the most unavailable were apatites, strengite, dufrenite, variscite and some leuco-phosphites. Seventeen organic phosphates have been tested and only ferric phytate was poorly available, but not sufficient to account for the slow mineralization of phosphate from soil humus.

(2) MECHANISMS OF RELEASING PHOSPHATES.

Over 50 soils have been examined for the presence of bacteria, actinomycetes and fungi capable of solubilising calcium phosphates, but they were detected in 5 soils only, most of which were acidic. The rhizosphere organisms from over 50 plants were also examined, but none was detected. This is contrary to the findings of Gerretsen in Holland, who used an excessively sensitive medium. Acid producing fungi dissolved much more calcium phosphate than acid forming bacteria.

RHIZOBIUM STUDIES.

Cytological studies have been made upon strains of *Rhizobium trifolii* associated with clovers and strains of rhizobia isolated from indigenous and naturalized alien legumes. Endospore formation has been found to be a general phenomenon, usually associated with the rough, non-gummy phase, but occasionally with the smooth, gummy phase. Sporulation enabled the organism to resist heat, and many cultures remained viable after 20 minutes at 100°. The progeny of such resistant spores of clover strains produced nodules on subterranean clover plants grown under aseptic conditions in test tubes. The sporing phase may be important in the persistence of the organism in soil under adverse conditions.

FRACTIONATION OF SOIL HUMUS.

A large continuous electrophoresis apparatus was built to fractionate humates, but consistent results could not be obtained because it was impossible to stabilise pH, temperature and outflow despite numerous trials with several buffers flowing at various rates through the electrode vessels, different voltages, different heads of pressure and varying the particle size. Instead, fractions were obtained by multiple paper electrophoresis but no proteins were detected and no marked concentration of nitrogenous substances occurred, although amino acids were present in acid hydrolysates.

OXIDATION OF HYDROCARBONS BY SOIL BACTERIA.

Work on the stimulation of oxidation of n-decane by monovalent cations using *Corynebacterium* sp. has been extended to other hydrocarbons and their derivatives. Using resting cells harvested from a medium deficient in K^+ ions, it was shown that 0.0008 M. K^+ in 7 hrs. increased oxygen consumption in presence of n-hexadecane, n-tetradecane, n-decane and n-octane by 231, 108, 122 and 190 per cent. respectively. With n-hexadecane and n-decane, NH_4^+ ions were as effective as K^+ ions, Rb^+ ions less so, but Cs^+ , Li^+ and Na^+ ions were without effect. The rates of oxidation of aliphatic monohydric alcohols (range ethanol to undecyl alcohol) and of the monocarboxylic acids (range acetic to n-decyl) were unaffected by the addition of K^+ ions thus suggesting that K^+ ions exert their influence before the formation of alcohols and acids. Two different corynebacteria showed this K^+ stimulation more on lyophilised cells than fresh cells.

"SPINDLE STAND" OF PINES.

Pot experiments have been completed on the possible cause(s) of "spindle stand" in *Pinus radiata* growing in Young sand from Mount Burr. The unthrifty appearance of the pines could not be improved by providing more water, more mycorrhiza or more needle litter, nor by eliminating possible toxic factors with clays, lime, E.D.T.A. or leaching. Vigorous, healthy pines could be obtained by applying fertilizers containing N, P, S, K, Zn and Cu. The addition of over 50 other elements produced no further beneficial effects after a year. It is thought that "spindle stand" might be due to a multiple deficiency of essential elements and it is doubtful whether it would be economically sound to apply fertilizers and establish pines on such a deficient sand.

6. CLAY MINERALOGY.

During 1955 the Clay Mineralogy Section moved from the Waite Institute to the laboratories of the University Department of Geology. Further equipment has been added, including a single crystal and a Weissenberg camera. These cameras will be used for studying the structures of clays and related minerals and for following in detail the structural changes involved as rock minerals weather to clays. The Raymax X-ray unit has been modified to incorporate electrostatic focussing of the electron beam with an improvement in focus and increased emission stability. The replacement of the old type vacuum seals, of this unit, with neoprene rings and the incorporation of vacuum valves has improved its operation.

PHOSPHATE MINERALS.

Some soils, although naturally high in phosphorus, behave towards plants as if phosphorus deficient. Other soils render unavailable much of the phosphorus which is added as superphosphate. It is probable that the naturally unavailable and the fixed phosphates are related and a knowledge of their nature is desirable. Phosphates in soils are divided into organic, adsorbed and mineral forms, but more specific information on them has been difficult to obtain—largely because of the small amounts in the soil. Using refined X-ray diffraction techniques, some naturally-occurring phosphates have been identified as belonging to the gorcexite ($\text{BaAl}_3(\text{PO}_4)_2(\text{OH})_5 \cdot \text{H}_2\text{O}$, Ce $\text{Al}_3(\text{PO}_4)_2(\text{OH})_6$) florencite series. These were concentrated in the 0.5-5 micron fraction of the soils and could be obtained almost pure by dissolving the silicate minerals in hydrofluoric acid. The density of the minerals was confirmed on these concentrates by analyses for phosphorus, barium and rare earths. These minerals have been extracted from soils from Queensland, New South Wales, and South Australia, so that, although unexpected, they are not to be regarded as oddities. In some of the soils more than 70 per cent. of the total phosphorus was present as one of the above minerals. The extreme insolubility of these phosphates is demonstrated by their occurrence in very highly weathered soils. The technique of concentrating in hydrofluoric acid bears this out. Microbiological assay of these minerals, extracted from soils, indicates that their phosphorus is extremely unavailable. The nature and occurrence of the minerals suggest that they are an active part of the soil profile and not just a residual of parent material.

In conjunction with studies in the Chemistry and Microbiology Sections, many phosphate minerals were checked for identity and purity.

SOIL AND OTHER ANALYSES.

Detailed mineralogical examination of the clays of a large group of soils from the Barossa Valley, South Australia, has been carried out in connection with the soil survey of the area. Other clays from Northern Territory, New South Wales and Queensland have been analysed. Clays from soils and various minerals from the Antarctic have been identified for the Antarctic Survey and at the request of Sir Douglas Mawson.

In the analysis of clays from many parts of Australia, illite is found to be a major component yet many of these clays differ considerably in physical and chemical properties. It is suspected that the behaviour of clay illite is markedly dependent on the amount of hydration it has undergone. Such properties as swelling and potassium fixation would be related to its hydration. A technique has been developed for investigating the low angle scattering of clays using the Philips diffractometer and it is hoped that these studies will enable a distinction to be made between the various illites.

FLUORESCENT X-RAY SPECTROSCOPY.

This technique has been developed further with increased accuracy and sensitivity. Under suitable conditions an accuracy of 2 per cent. can be attained, without the use of internal standards, while for some elements concentrations as low as 5 parts per million can be measured. During the year various soils have been analysed for Fe, Ti, Zn, Zr, Cu, Sr, Pr, Nd, and Ba, while plant and liver specimens have been analysed for Fe, Cu, and Zn. The latter analyses have been made with the co-operation of officers of the Division of Biochemistry

and General Nutrition, who are interested to see if the technique is suitable for biological specimens. The X-ray analyses of these specimens agreed well with results obtained by conventional chemical methods. The X-ray technique is much quicker and involves almost no pretreatment of the sample.

7. SOIL MECHANICS.

Although the Section has its headquarters at Melbourne for the time being, work has proceeded actively in South Australia, especially in the Adelaide area. Investigations have been made of the soil conditions in relation to building foundations at two centres in Adelaide—Broadview Gardens and Northfield. At the former failure of houses was found to be due to soil movements beneath foundations following development of saturated conditions close to the surface. Water tables at shallow levels were formed due to the presence at variable depths of 2 to 10 ft. of a slowly permeable clay on which ponding of surplus water occurred. At Northfield, the soil formations consisted of stratified clays, calcareous materials and often a slowly permeable clay on which free water might accumulate, all underlain by a compact, partially cemented sand. Reports on the conditions at both centres and recommendations to deal with them have been prepared.

In association with the S.A. Highways Department an installation of equipment has been made in the highway near Bordertown to follow moisture changes occurring seasonally in a transect from under the centre of the paved surface to the undisturbed adjoining area under natural vegetation. Regular readings are to be made for a period of years sufficient to establish the associated moisture status.

Publications of the Staff of the
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1. PEDOLOGY AND SOIL SURVEY.

- G. Blackburn and F. R. Gibbons. "A Reconnaissance of the Soils of the Shire of Kowree, Victoria." C.S.I.R.O. Divn. of Soils: Soils and Land Use Series No. 17. 1956.
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Oenological Research

(Chairman of Committee: PROFESSOR J. A. PRESCOTT, C.B.E., D.Sc., F.R.S.)

Staff as at 31st December, 1955.

Acting Officer in Charge: J. C. M. FORNACHON, M.Sc., B.Ag.Sc.

Research Officer: B. C. RANKINE, M.Sc.

Assistant: MRS. Y. HUTCHINSON.

Oenological research at the Waite Institute is conducted under a special committee of the C.S.I.R.O. representative of the wine industry and the scientific disciplines concerned. It is financed in equal parts by the Australian Wine Board and the Federal Treasury.

1. WINE YEASTS.

The investigation on these micro-organisms was concerned with finding out the best conditions for their use in winemaking. Experiments were carried out in small fermenters in wineries and the populations of micro-organisms were studied during the period before fermentation of the grape juice. The most important condition for their successful use appears to be that the actively-fermenting selected yeast should be added as soon as possible after the grapes are crushed. Once the grape juice has started to ferment under the influence of the indigenous microflora, the addition of a selected yeast, except in massive doses, appears to be of no value. Various strains of yeasts were tested in small winery fermentations and selections were made on the basis of clarity of the fermented juice and alcohol yield.

2. MALO-LACTIC FERMENTATION.

Examination of many Australian wines has shown that bacterial decomposition of malic acid (malo-lactic fermentation) is a common occurrence in our wines. However, it has been found that the bacteria grow most readily in wines with high pH values and that the malo-lactic fermentation occurs very irregularly in wines with pH values of 3.4 or lower. These are the wines which would be most likely to be improved by such a fermentation and current investigations are concerned with factors affecting the tolerance of the bacteria towards acidity.

A number of strains of bacteria capable of decomposing malic acid have been isolated from Australian wines and identified. All of these have been found to belong to one or other of two species: *Lactobacillus buchneri* and *Lactobacillus fermenti*. Considerable differences have been noticed in the rates of decomposition of malic acid by different strains and in the tolerances of different strains to low pH values and to alcohol.

Growth of the bacteria in wine is stimulated by the presence of yeast autolysate and is inhibited by anaerobic conditions.

3. TREATMENT OF WINE WITH ION-EXCHANGE RESINS.

This work was undertaken to see whether ion-exchange could improve wine quality by preventing potassium bitartrate deposition (and thus obviating the need for refrigeration) and adjusting acidity.

Experiments were carried out in the laboratory using various ion-exchange resins and different types of wine, and were later extended to small pilot-plant scale in the winery. The results were very promising and indicated that ion-exchange treatment could eliminate potassium bitartrate deposition, adjust acidity as required, and partially remove metallic contamination without adversely affecting the flavour of the wine. In some cases the flavour was improved. It is likely that ion-exchange treatment will be applied to wine commercially in the near future.

4. EFFECT OF REFRIGERATION ON WINE COMPOSITION.

The main purpose of refrigeration is to precipitate potassium bitartrate, but there are secondary effects on wine composition which are of interest, and accordingly the effect of refrigeration on wine composition was examined. Samples of wine before and after commercial refrigeration were collected and analysed and changes were observed in the following constituents: tartaric acid, potassium, titratable acid, pigment, iron, copper, total nitrogen and pH.

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